TECHNICAL MEMORANDUM NO. 6

HUMAN HEALTH RISK ASSESSMENT
903 PAD, MOUND, AND EAST TRENCHES AREAS
OPERABLE UNIT NO. 2
MODEL DESCRIPTION

DRAFT FINAL

ROCKY FLATS PLANT

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT DEPARTMENT

January 1993

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This document provides a description of the models selected to perform groundwater, surface-water, and air modeling for Rocky Flats Plant Operable Unit No. 2 (OU-2) in support of the Human Health Risk Assessment (risk assessment), which is part of the OU-2 Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI). This document does not describe the technical approach to be used in applying selected models to the site-specific conditions at OU-2; that will be described in detail in the Phase II RFI/RI Report.

The objectives of the modeling are as follows:

1) To support the Human Health Risk Assessment portion of the RFI/RI Report for OU-2. This will be accomplished by simulating the transport of chemicals of concern from OU2 to potential exposure points for human receptors under present and anticipated future site conditions.

2) To support the evaluation of potential remedial alternatives for the Feasibility Study at OU-2.

A conceptual site model (CSM) has been developed to identify and evaluate the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors at OU-2. The purpose of the CSM is to identify human exposure pathways to be quantitatively evaluated in the Human Health Risk Assessment. Exposure pathways chosen for evaluation in the risk assessment that include transport media such as groundwater, surface-water, and air, may require fate and transport modeling to estimate chemical exposure point concentrations. The following document describes the exposure pathways to be evaluated in the Human Health Risk Assessment that will require such modeling and identifies the mathematical models that will be used to estimate exposure point concentrations. The models are based on data that have been collected at the site as part of Phases I and II of the RFI/RI for OU-2. At the time this technical memorandum was prepared, only a portion of the soil and groundwater data from the Phase II investigation were available. If additional data that are substantially different than those used in developing this technical memorandum become available, revisions to the modeling approach may become necessary.

The following models were selected to meet the requirements and objectives of the modeling study:

- The U.S. Geological Survey (USGS) MODFLOW numerical model for groundwater flow, and the MT3D numerical model for groundwater contaminant fate and transport in the Rocky Flats Alluvium and Arapahoe Formation No. 1 Sandstone. The ONED3 analytical model for groundwater contaminant fate and transport in the colluvium.

- The Universal Soil Loss Equation, Soil Conservation Service (SCS) Curve Number Equation, and Mass Balance Equation for surface-water fate and transport.

- The Superfund Exposure Assessment Manual (SEAM) Models for soil gas fate and transport, a box model for on-site ambient air contaminant fate and transport, and Fugitive Dust Model (FDM) for off-site ambient air contaminant fate and transport of OU-2 source air emissions.

Data available for use as input for the modeling activities were evaluated based on a review of previous and ongoing investigations, and general literature. Tables 3-1, 3-2, 3-3, and 3-4 summarize the data currently available to estimate model input parameters. Additional data from the Phase II RFI/RI investigation will be used in the modeling effort once those data become available.

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site specific. The data values or ranges of values are not intended to be fixed or final. The ranges are presented to convey what is currently known of the potential variability in the parameter values that may be used in the models.

1.0 INTRODUCTION

This document provides a description of the models selected to perform groundwater, surface-water, and air modeling for the OU-2 Human Health Risk Assessment. The results of the modeling will be used as exposure point concentrations in the Human Health Risk Assessment, which is part of the OU-2 Phase II RCRA Facility Investigation/Remedial Investigation. The RFI/RI is pursuant to a Compliance Agreement between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH), dated July 31, 1986; and the Federal Facility Agreement and Consent Order (FFACO) [known as the Inter-Agency Agreement (IAG)], dated January 22, 1991. The DOE Environmental Restoration Program (ERP) was formed to identify, investigate, and, if necessary, remediate contaminated sites at DOE facilities. The program, in fulfilling this mission, addresses RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) issues. In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study," respectively.

This technical memorandum is meant to be reviewed in conjunction with the Human Health Risk Assessment Exposure Scenarios technical memorandum for OU-2 (DOE 1992b). The reader of this technical memorandum is referred to that document for additional information or details on the exposure scenarios to be used for OU-2.

The remainder of Section 1.0 includes a discussion of the purpose of this technical memorandum and the objectives of the modeling activities (Section 1.1), and a brief description of the site location and general site conditions (Section 1.2). Section 2.0 presents the conceptual site model and exposure pathways to be evaluated in the risk assessment for OU-2, and Section 3.0 presents descriptions of the selected models for groundwater, surface-water, and air, and a summary of model input parameter values. Section 4.0 presents a summary, and Section 5.0 is a list of references used in preparing this technical memorandum.

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide a description of appropriate groundwater, surface-water, and air models for use at OU-2. This document fulfills the IAG requirements (IAG 1991, Section VII.D.1.b) that state:

> "... DOE shall submit for review and approval a description of the fate and transport models that will be utilized, including a summary of the data that will be used with these models. Representative data shall be utilized, and the limitations, assumptions and uncertainties associated with the models shall be documented."

The model selection process focuses on models appropriate for simulating processes affecting the migration of contaminants through the saturated Upper Hydrostratigraphic Unit (UHSU) and through surface-water, and the airborne transport of contaminants. This document does not address the application of the selected models to the site-specific conditions at OU-2; that will be included in the Phase II RFI/RI Report.

Modeling activity quality assurance is covered by the site-wide quality assurance plan (EG&G 1991b). Modeling quality assurance (QA) includes model verification, checks on calculations, and technical review of modeling methods, assumptions, results, and interpretations.

The objectives of the modeling are as follows:

1) To support the Human Health Risk Assessment portion of the RFI/RI Report at OU-2. This will be accomplished by simulating the transport of chemicals of concern from OU-2 to potential exposure points for human receptors under present and anticipated future site conditions.

2) To support the evaluation of potential remedial alternatives for the Feasibility Study at OU-2.

1.2 SITE LOCATION AND GENERAL SITE CONDITIONS

The Rocky Flats Plant (RFP) is a government-owned and contractor-operated facility that is part of the nationwide nuclear weapons production complex. RFP was operated for the U.S. Atomic Energy Commission (AEC) from the RFP's inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for RFP was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by DOE in 1977. Dow Chemical USA, an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975, when it was succeeded by Rockwell International. On January 1, 1990, EG&G Rocky Flats, Inc. succeeded Rockwell International.

RFP's primary mission has been to produce metal components for nuclear weapons. These components are fabricated from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel). Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and disposal of solid radioactive materials at another DOE facility. However, historically, the operating procedures included both on-site storage and disposal of hazardous and radioactive wastes. Preliminary assessments under the ERP identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

RFP is located on 6,550 acres of federally owned land in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1). Surrounding cities include Boulder, Broomfield, Superior, Westminster, and Arvada, which are located less than ten miles to the northwest, east, and southeast. Within RFP is a Protected Area (PA) or security area surrounded by a buffer zone of approximately 6,150 acres. A general description of RFP is presented in this section. For a more detailed description, please refer to the RFI/RI Work Plan (alluvium) for OU-2 (DOE 1991).

This Phase II RFI/RI modeling technical memorandum addresses OU-2, which contains the 903 Pad, Mound, and East Trenches areas located on the east side of the RFP security area. Several individual hazardous substances sites (IHSSs) are included in each area. Figure 1-2 shows the locations of these areas, and the IHSSs within each area. The following sites are designated as IHSSs at OU-2:

- 903 Drum Storage Site (IHSS Ref. No. 112)
- 903 Lip Site (IHSS Ref. No. 155)
- Trench T-2 Site (IHSS Ref. No. 109)
- Reactive Metal Destruction Site (IHSS Ref. No. 140)
- Gas Detoxification Site (IHSS Ref. No. 183)
- Mound Site (IHSS Ref. No. 113)
- Trench T-1 Site (IHSS Ref. No. 108)

- Oil Burn Pit No. 2 Site (IHSS Ref. No. 153)
- Pallet Burn Site (IHSS Ref. No. 154)
- East Trenches Area Burial Trenches (IHSS Ref. Nos. 110 & 111.1-111.8)
- East Trenches Area Spray Irrigation Sites (IHSS Ref. Nos. 216.2 and 216.3)

A more detailed description of each IHSS and the types of associated contamination can be found in the RFP Comprehensive Environmental Assessment and Response Program (CEARP) Phase I Installation Assessment and the RCRA Part B Operating Permit Application as reported in DOE (1991).

1.2.1 Physical Setting

The natural environment of RFP and its vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. RFP is directly east of the north-south trending Front Range and is located approximately sixteen miles east of the Continental Divide, on a broad, eastward-sloping plain of coalescing alluvial fans developed along the Front Range at an elevation of approximately 6,000 feet above mean sea level. The fans extend approximately five miles in an eastward direction from their origin at Coal Creek Canyon and terminate on the east, at a break in the slope, as low rolling hills. The operational area at RFP is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).

Three intermittent streams drain RFP with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern corner of RFP and flows northeast through the buffer zone to its off-site confluence with Coal Creek. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the RFP Protected Area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir, which is approximately one mile east of the confluence. This flow is currently routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern RFP buffer zone and flows eastward to Standley Reservoir. OU-2 is bounded on the north by South Walnut Creek and on the south by Woman Creek.

1.2.2 Meteorology

In general, winds blow from northerly through westerly directions approximately 64 percent of the year. Southerly wind directions occur with less frequency (approximately 20 percent of the year), while easterly wind directions are infrequent (only 11 percent of the year). Wind patterns are heavily influenced by synoptic scale meteorological patterns, convective storms, and mountain/valley flows.

The wind speeds are greatest from the northwesterly direction. Wind speeds in excess of 15 meters per second (34 miles per hour) are regularly observed. Winds are calm approximately 5 percent of the year. Figure 1-3 presents a wind rose illustrating the wind patterns in the region for the year, 1990. This wind rose is generated from wind speed and direction data recorded at an on-site meteorological tower at a monitoring height of 61 meters.

Atmospheric stability at the site is generally neutral (Class D) to slightly stable (Class E). Periods of very stable (Class F) and unstable (Classes A through C) stability occur less than 20 percent of the year (DOE 1992a). Neutral to slightly stable conditions generally allow for uniform dispersion of contaminants. Very stable atmospheric conditions inhibit dispersion. Unstable atmospheric conditions aid in dispersing contaminants.

Precipitation at the Rocky Flats Plant averages 380 millimeters (15 inches) per year. A majority of the precipitation is in the form of snowfall and occurs during the winter and spring seasons. Average annual total snowfall is 2160 millimeters (85 inches). The summers are generally dry with isolated thunderstorms contributing up to 30 percent of the annual precipitation. Autumn is the driest period of the year. Annual potential free-water evaporation is approximately 1144 millimeters (45 inches) which is significantly greater than the annual precipitation (DOE 1992).

1.2.3 Geology

The near-surface geologic materials at RFP consist of surficial unconsolidated deposits and shallow bedrock. The surficial deposits at OU-2 consist of pediment alluvium, colluvium, valley-fill alluvium, and artificial fill that unconformably overlay bedrock. Surficial deposits at RFP are Quaternary (Pleistocene - Holocene) in age. Near-surface bedrock consists of the Arapahoe and Laramie Formations, which are Cretaceous in age. The regional dip of the bedrock in the vicinity of OU-2 is approximately two degrees to the east. The bedrock formations, as well as the Rocky Flats Alluvium, are shown on Figure 1-4 and will be discussed below.

The Rocky Flats Alluvium is a pediment gravel deposited in a laterally coalescing alluvial fan environment. It was deposited across a gently sloping erosional surface cut into the underlying soft bedrock. The deposit consists of poorly to moderately sorted, poorly stratified clays, silts, sands, gravels, and cobbles. The colors of the Rocky Flats Alluvium include light to dusky brown, dark yellowish-orange, grayish orange, and dark gray. The Rocky Flats Alluvium ranges in thickness from 0 to 50 feet beneath OU-2. Subsequent dissection and headward erosion by creeks to the south and north of OU-2 have cut through the alluvium into the underlying bedrock. This dissection has left the base of the alluvium exposed along the valley slopes, approximately 40 to 120 feet above the present valley floor. Remnants of younger terrace deposits of the Verdos and Slocum Alluviums occur at lower elevations in some locations along the valley slopes of OU-2.

Colluvial materials in OU-2 were derived from slope wash and creep of the Rocky Flats Alluvium, and the Arapahoe and Laramie Formations. The colluvium consists of clays, sands, and gravels, and ranges in thickness from a few feet to 20 feet. Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock contact along the hillsides. Artificial fill and disturbed ground occur in localized areas of the 903 Pad, Mounds, and East Trenches areas. Recent valley-fill alluvium occurs in the active stream channels of Walnut and Woman Creeks. This material is derived from reworked older alluvial, colluvial, and bedrock deposits.

The Cretaceous-age Arapahoe Formation is the uppermost bedrock formation and unconformably underlies the unconsolidated material at OU-2. The Arapahoe Formation, which is approximately 150-feet thick (DOE 1991) in the vicinity of RFP, is the product of a fluvial depositional environment and is composed of channel, point bar, and overbank fluvial deposits of sandstones, claystones, siltstones, and occasional lignitic coal seams and ironstones. The Arapahoe Formation outcrops at certain locations along the Walnut and Woman Creek stream valleys.

The sandstones of the Arapahoe Formation are primarily very fine- to coarse-grained quartz sands, moderate to well-sorted, and subangular to well-rounded. Some clay rip-up clasts and iron nodules are present in the sandstones of the Arapahoe Formation. The colors of the sandstones are light gray to olive gray. The weathered sandstones are mainly dusky yellow to dark yellowish-orange, as a result of iron oxide staining. The colors of the claystones are light to medium gray and dark yellowish-orange when weathered. Individual sandstone lenses are local in extent and may or may not be in hydraulic communication with one another. Multiple, overlapping sandstone sequences exist within the Arapahoe Formation (EG&G 1992).

The uppermost sandstone unit in the Arapahoe Formation is referred to as the No. 1 Sandstone. The No. 1 Sandstone unconformably underlies the Rocky Flats Alluvium and colluvium, and is generally located on the northwest side of the 903 Pad area and north of Central Avenue in the Mound and East Trenches areas of OU-2. The No. 1 Sandstone is a heterogeneous sandstone body consisting of sandstone with interbedded siltstone and claystone layers. Medium- to coarse-grained sand and an occasional conglomeratic sandstone have been identified at the base of the No. 1 Sandstone in OU-2. The unit ranges from 0 to 40 feet in thickness. The No. 1 Sandstone is interpreted to be a fluvial sand channel deposit that incised into the underlying material. The No. 1 Sandstone extends laterally between the 903 Pad and Mound areas, but does not extend laterally between the Mound and East Trenches areas. The northern edge of the No. 1 sandstone beneath OU-2 is an erosional boundary along the South Walnut Creek drainage. The southern edge of the No. 1 Sandstone beneath OU-2 is a depositional boundary bounded by claystone. As such, only limited outcropping or subcropping of the No. 1 Sandstone occurs along the Woman Creek drainage.

The Laramie Formation is Cretaceous in age and gradationally underlies the Arapahoe Formation at OU-2. The Laramie Formation, which is approximately 800 feet thick (DOE 1991) in the vicinity of RFP, is divided into two units. The lower unit, which is approximately 250-feet thick, is composed of several sandstone layers and many coal seams. The upper unit, which is approximately 550-feet thick, is composed of deltaic claystones, siltstones, some fluvial sandstones, and an occasional coal layer. The sandstones in the lower unit are light to medium gray, fine- to coarse-grained, poorly sorted, and subangular. The upper unit claystones and siltstones are light olive gray to olive-black in color with some carbonaceous material.

1.2.4 Hydrogeology

The uppermost groundwater beneath OU-2 occurs in the UHSU, which consists of the Rocky Flats Alluvium, colluvium, valley fill and the subcropping No. 1 Sandstone of the Arapahoe Formation. The elevation of groundwater in the alluvium beneath OU-2 varies seasonally. In general, groundwater in the UHSU exists under unconfined conditions, however partially confining conditions may exist in portions of the No. 1 Sandstone that are bounded laterally or vertically by claystone. Groundwater flow in the Rocky Flats Alluvium is generally from the west to the east, and locally follows the scoured lows on the top of the underlying bedrock.

Groundwater flow in the No. 1 Sandstone is generally from west to east on a large scale, but may be locally controlled by the geometry of the sandstone body. Groundwater in the colluvium mantling the valley slopes bordering OU-2 has localized flow from seeps and springs on the valley slopes toward South Walnut and Woman Creeks.

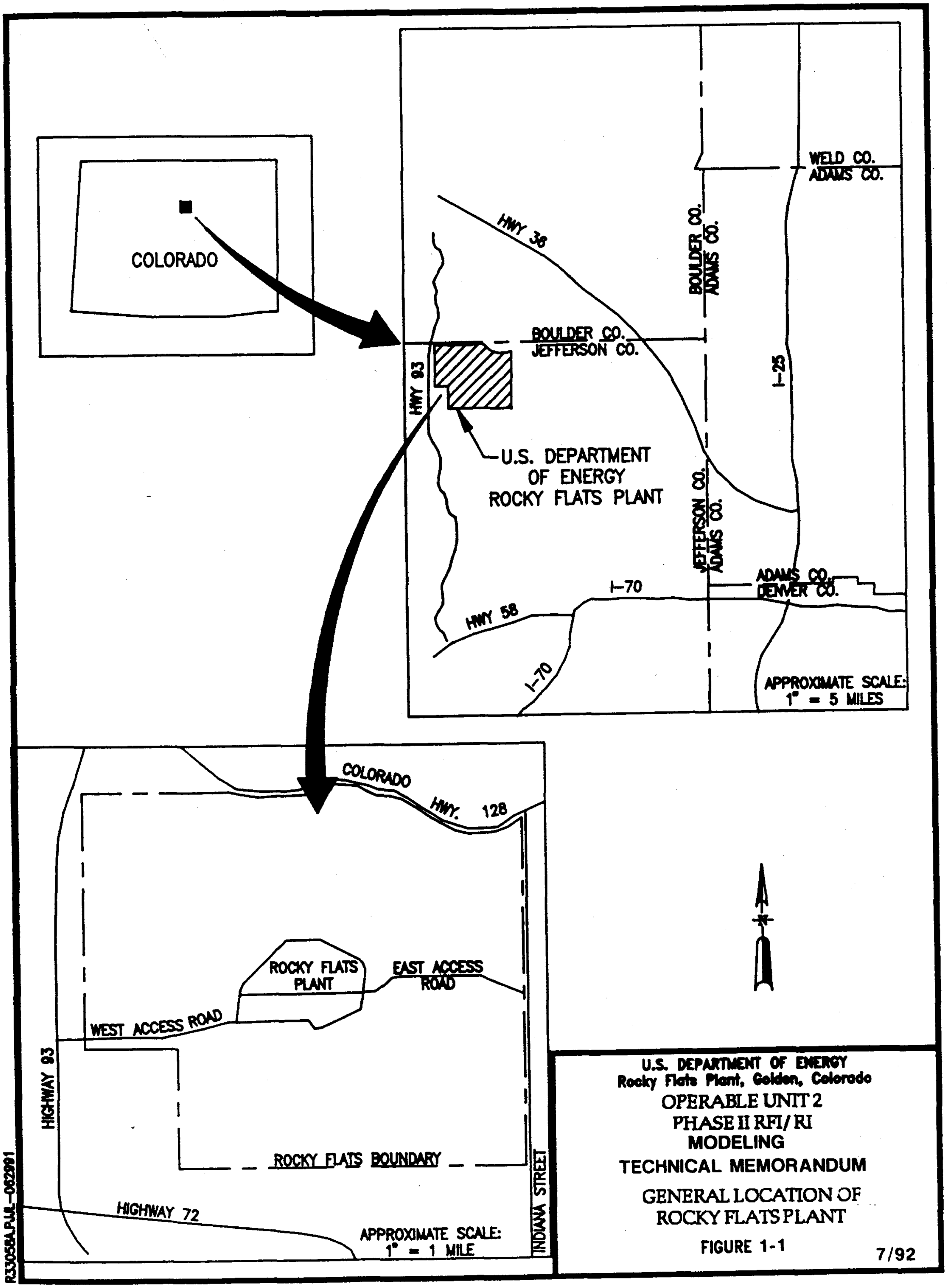
Recharge to the UHSU beneath OU-2 occurs primarily from infiltration of precipitation, and from groundwater inflow within the UHSU from the area west of OU-2. Based on water level measurements in wells completed in the UHSU of OU-2, groundwater levels vary substantially (i.e., up to 27 feet) in response to seasonal changes. Groundwater levels reach their highest in the spring and early summer, when precipitation is high and evapotranspiration is low. Groundwater levels decline during the remainder of the year with periodic changes due to precipitation events. Many wells completed in the alluvium go dry during periods of low water levels.

Groundwater discharge from the UHSU occurs at seeps and springs on the hillsides of OU-2, where the Rocky Flats Alluvium and No. 1 Sandstone outcrop or subcrop along the valleys of South Walnut and Woman Creeks. In general, the seeps occur at the contact between the Rocky Flats Alluvium and underlying bedrock, or the No. 1 Sandstone (where present) and the underlying claystone bedrock. This water then flows downslope along the ground surface or through the colluvial deposits to South Walnut or Woman Creeks.

1.2.5 Surface-Water Hydrology

Two streams, South Walnut Creek and Woman Creek, are located in the vicinity of OU-2 and flow generally from west to east. Although seasonal flows can be low in both streams, Woman Creek receives continuous flow from Antelope Springs, and South Walnut Creek receives continuous seep flow from the 750 Pad Area. Intermittent groundwater seeps or springs occur near IHSS 140 in the 903 Pad Area, IHSS 154 in the Mound Area, and northeast of the East Trenches Area, along the south side of South Walnut Creek drainage. Figure 1-2 illustrates the current surface-water bodies in the Woman and Walnut Creek drainages. Detention Pond C-1 is located on Woman Creek. Pond C-2 receives flow only from the South Interceptor Ditch (SID), which lies on the northern flank of the Woman Creek drainage. The SID collects runoff from the southern RFP security area and diverts it to Pond C-2. The Pond C-2 flow is not discharged to Woman Creek, but is pumped to the Broomfield Diversion Ditch approximately semi-annually. Plans have been made to also pump to pond B-5 in the future.

Detention Ponds B-1 through B-5 are located on South Walnut Creek. Flow is diverted around Ponds B-1 and B-2 to Ponds B-3 and B-4 which are flow-through ponds. The South Walnut Creek water flows to Pond B-5, where it is transferred approximately every 45 days to Pond A-4. South Walnut Creek, which drains a portion of OU-2, flows eastward and is currently diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Woman Creek drains the southern portion of OU-2 and normally discharges via Mower Ditch into Mower Reservoir and Standley Lake. During periods of high flow, Woman Creek may discharge directly to Standley Lake.



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OPERABLE UNIT 2
PHASE II RFI/RI
MODELING
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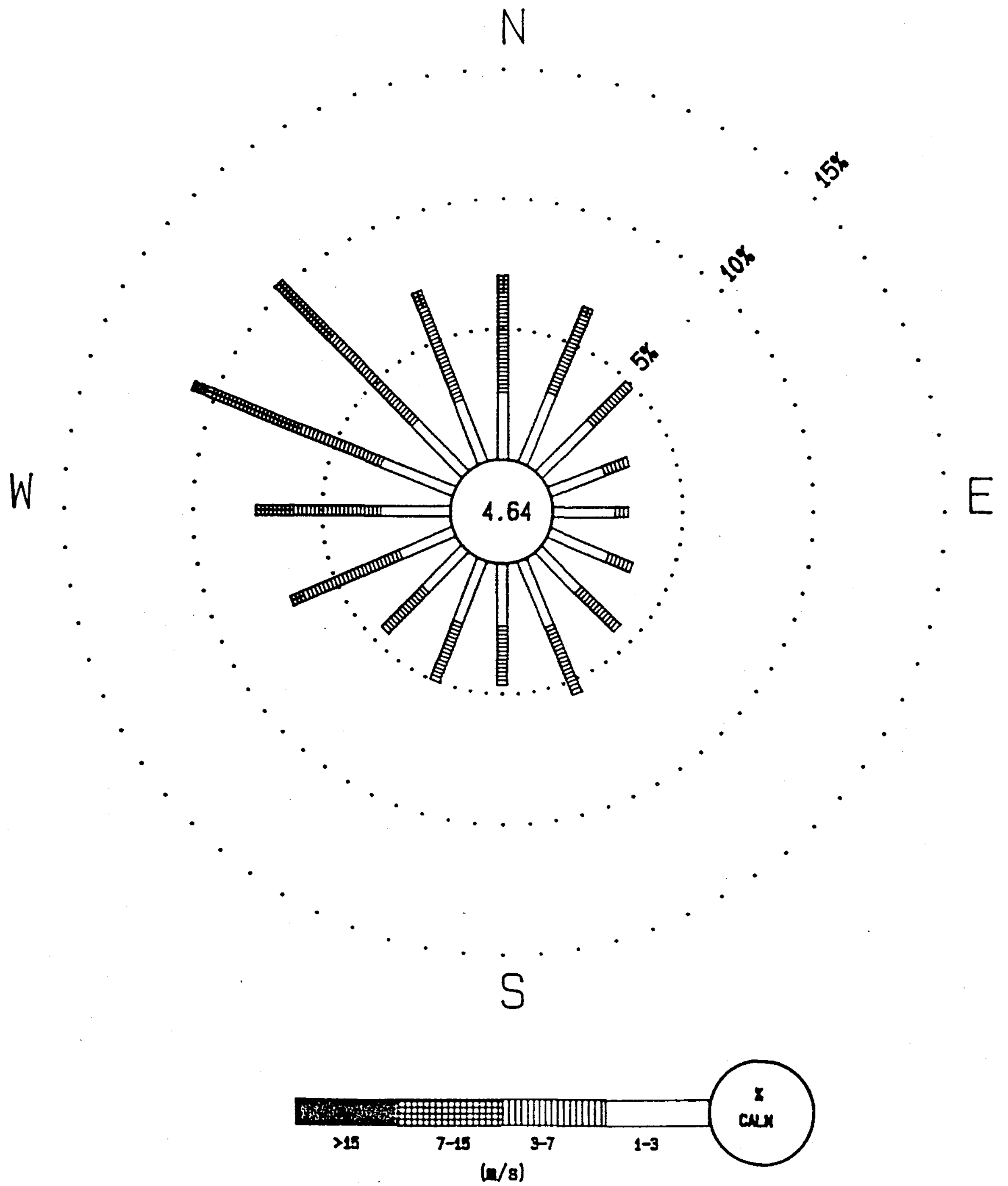
GENERAL LOCATION OF
ROCKY FLATS PLANT

FIGURE 1-1

7/92



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1990 ANNUAL WIND ROSE FOR
THE ROCKY FLATS PLANT

FIGURE 1-3

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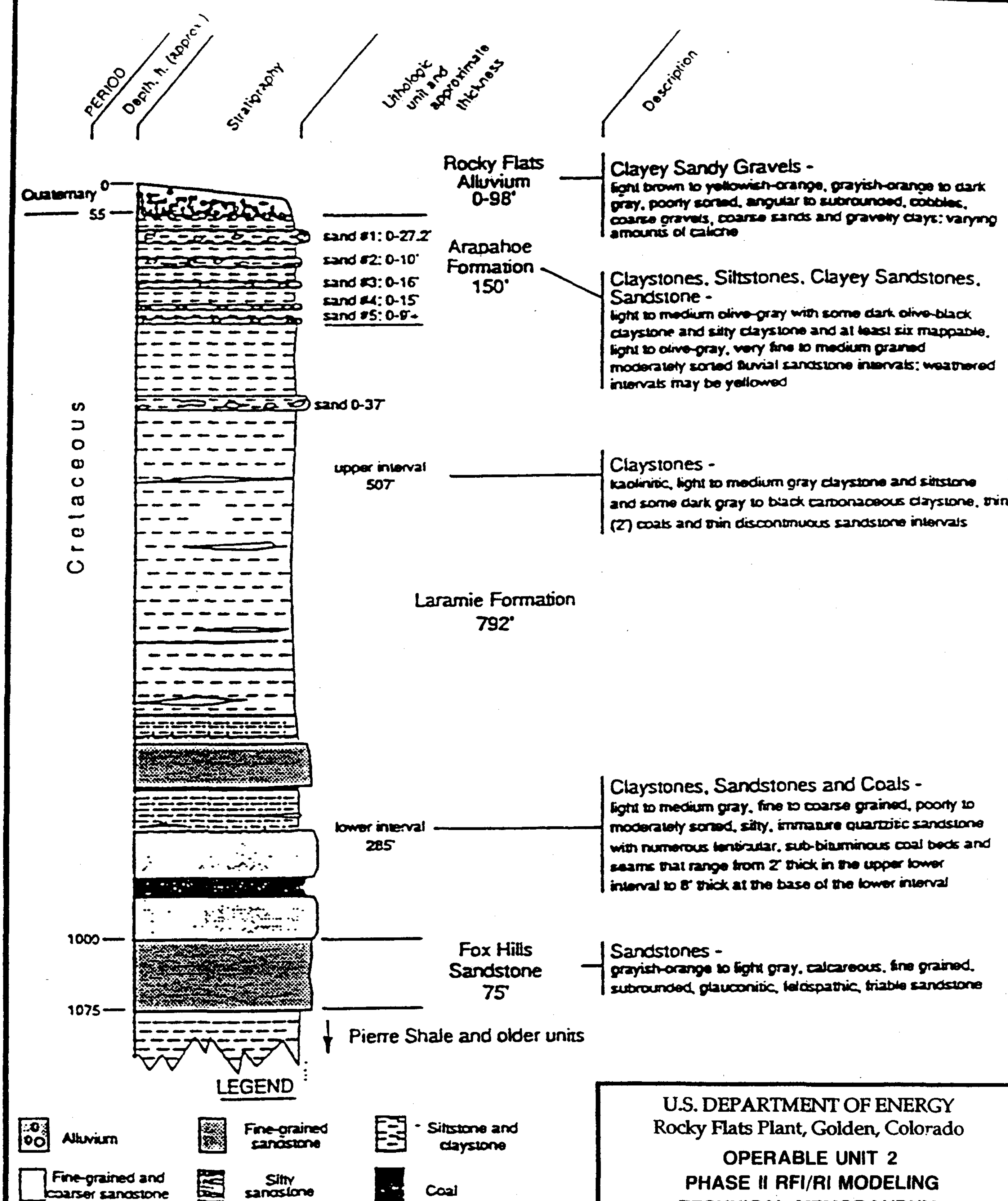

Modified from LeRoy & Weimer, 1971, and Weimer, 1973

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TECHNICAL MEMORANDUM

NEAR SURFACE
STRATIGRAPHIC SECTION

FIGURE 1-4 7/92

2.0
GENERAL CONCEPTUAL MODEL OF OPERABLE UNIT TWO

2.1 CONCEPTUAL SITE MODEL

This section discusses the potential release and transport of chemicals from OU-2 and describes pathways by which the receptor populations may be potentially exposed to chemicals of concern. An exposure pathway describes a specific environmental pathway by which an individual can be exposed to chemical constituents present at or originating from a site. An exposure pathway includes five necessary elements:

- A source of chemicals
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- A human intake route

Each one of these five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete and relevant pathways will be addressed in the Human Health Risk Assessment for OU-2.

An exposure point is a specific location where human receptors can come in contact with site-related chemicals. The objective of this technical memorandum is to identify fate and transport models that will be used to calculate exposure point concentrations for the Human Health Risk Assessment. Environmental media that may transport chemicals of concern from OU-2 to potential human exposure points are presented in the conceptual site model for OU-2 (presented below). The media associated with exposure pathways that will require fate and transport modeling are discussed in the following subsections. A more detailed summary of potentially exposed human receptor populations and exposure pathways for OU-2 is presented in the Human Health Risk Assessment Exposure Scenarios technical memorandum (DOE 1992b).

Potentially exposed receptor populations selected for quantitative assessment in the Human Health Risk Assessment include the following:

- Current on-site worker
- Current off-site resident
- Future on-site worker
- Future on-site ecological researcher
- Future on-site and off-site residents

Exposure points were selected for each of the above receptors so that the reasonable maximum exposures will be quantitatively evaluated. Evaluation of potential health risks for receptors at these points will bound the risks for receptors at other exposure points not selected for quantitative evaluation. The following exposure points were selected for the receptors identified above. These locations are also presented in Figure 2-1.

Current Scenario

- Residential receptor. Nearest residence to RFP (located at the southeast corner of the RFP property boundary) and nearest residence to RFP that is in the predominant wind direction.

- Occupational receptor. On-site, within the OU-2 area.

Future Scenario

- Occupational receptor. On site, within and near the OU-2 IHSSs areas.
- Ecological researcher receptor. On site, within RFP buffer zone east of IHSSs areas, bounded by Woman and South Walnut Creeks.
- Residential receptors.
  Hypothetical off-site residences at the following locations:

  (1) Point at which South Walnut Creek intersects the eastern RFP property boundary.
  (2) Point at which Woman Creek intersects the eastern RFP property boundary.

Hypothetical on-site residence within the OU-2 area bounded by Woman and Walnut Creeks.

Exposure pathways to be quantitatively evaluated in the Human Health Risk Assessment were identified using a conceptual site model (Figure 2-2). The CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

In the CSM (Figure 2-2), potentially complete and relatively significant exposure pathways are designated by an "S." Potentially complete and relatively insignificant exposure pathways are designated by an "I." Both potentially complete, relatively significant and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment (designated as "S" and "I", respectively, in Figure 2-2). Quantitatively addressing both significant and relatively insignificant exposure pathways will reduce the possibility of underestimating risk. Negligible or incomplete exposure pathways are designated by an "N" and are not addressed in the risk assessment. For a more detailed description of the pathways, along with their assumptions, please see the Human Health Risk Assessment Exposure Scenarios technical memorandum (DOE 1992b).

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the Human Health Risk Assessment is presented in Table 2-1. Those exposure pathways are consistent with the CSM shown on Figure 2-2. Exposure pathways that will require fate and transport modeling are those that include groundwater, surface-water, and air as transport media to exposure points. These include the following exposure pathways:

<u>Current Off-site Resident:</u>

- Soil ingestion (following deposition of airborne particulates)
- Dermal contact with soil (following deposition of airborne particulates)
- Ingestion of vegetables (following deposition of airborne particulates)
- Inhalation of airborne particulates

Current On-site Worker:

- Soil ingestion
- Dermal contact with soil
- Inhalation if airborne particulates
- External irradiation

Future On-site Workers (Office and Construction):

- Soil ingestion
- Dermal contact with soil
- External irradiation
- Inhalation of Volatile Organic Chemicals (VOCs) in indoor air - office worker only
- Inhalation of airborne particulates

Future On-site Ecological Researcher:

- Soil ingestion
- Dermal contact with soil
- Surface-water/suspended sediment ingestion
- Dermal contact with surface-water/suspended sediment
- Inhalation of airborne particulates
- External irradiation

Future Off-site Resident:

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil
- Surface-water/suspended sediment ingestion
- Dermal contact with surface-water/suspended sediment
- Ingestion of homegrown vegetables (following surface deposition of airborne particulates)
- Inhalation of particulates

Future On-site Resident:

- Soil ingestion
- Dermal contact with soil
- Surface-water/suspended sediment ingestion
- Dermal contact with surface-water/suspended sediment
- Ingestion of homegrown vegetables
- Inhalation of particulates
- Groundwater ingestion
- Inhalation of VOCs in indoor air
- External irradiation

A brief discussion of the environmental media associated with the above exposure pathways and the potential fate and transport of chemicals in these media is presented in the following subsections. The models associated with these pathways are presented in Section 3.0.

2.2 GROUNDWATER

Figure 2-3 depicts the general conceptual model of the OU-2 UHSU groundwater flow and contaminant transport system, and illustrates the conceptual migration of contaminants from a source (e.g., the 903 Pad area) through the saturated zone in the UHSU to seeps along the hillsides adjacent to Walnut or Woman Creeks. Once the contaminants reach the seeps they migrate downslope in surface flow or near-surface groundwater flow in the colluvium to the creeks and are then transported via surface-water processes. Those processes are discussed in Section 2.3.

2.3 SURFACE-WATER

The surface-water model results will support human health risk assessment data needs for several exposure pathways shown in Figure 2-2. Stormwater runoff may transport contaminated soils to surface-waters through erosion with subsequent transport to downstream receptors. Potential intake of chemicals in surface-water via oral or dermal exposure will be evaluated in the risk assessment. Potential health risks associated with chemicals in suspended sediments will also be evaluated.

Surface-waters and suspended sediments may be impacted from the discharge of contaminated groundwater via seeps and springs. Once groundwater-borne contamination reaches surface-waters, the potential exposure pathways are identical to those described above for contaminated stormwater, i.e. ingestion and/or dermal contact of surface-waters. Figure 2-4 is a conceptual diagram of the surface-water model illustrating these pathways.

2.4 AIR

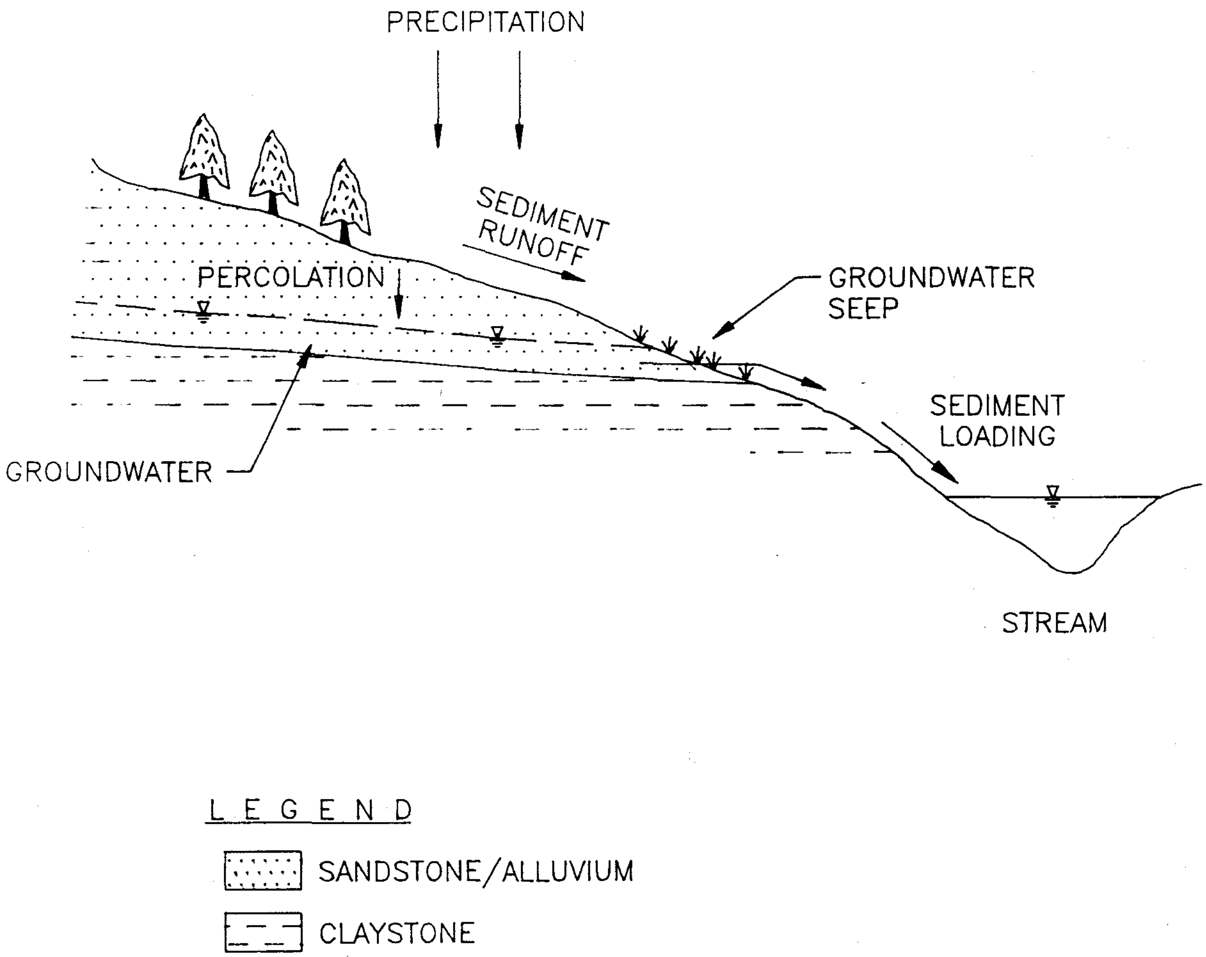
The air emissions and dispersion models selected to assess air contaminant concentrations at sensitive receptors will estimate exposure point concentrations for the exposure pathways associated with air transport shown on Figure 2-2. Volatile organic compounds (VOCs) may be transported through the vadose zone from underlying soils and will be subsequently entrapped within a hypothetical building located on top of OU-2 (volatilization into indoor air and subsequent inhalation by a future on-site worker). Chemicals in surface soils may be transported via fugitive dust emissions from OU-2 to on-site (inhalation of particulates by the future on-site worker and ecological researcher) and off-site exposure points (inhalation of particulates by the current and future residents). Fugitive dust emissions from OU-2 may also result in the deposition of chemicals in airborne particulates on surface soils and plants. Potential chemical intake and corresponding risks associated with these media will also be evaluated. A conceptual model for airborne exposure pathways is shown on Figure 2-5.

TABLE 2-1
ROCKY FLATS PLANT
OU-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED
IN THE OU-2 HUMAN HEALTH RISK ASSESSMENT

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Off-site resident	Current	Soil ingestion Dermal contact with surface soil Ingestion of vegetables (surface deposition of particulates) Inhalation of airborne particulates
On-site worker	Current	Soil ingestion Dermal contact with surface soil Inhalation of airborne particulates External irradiation
On-site worker (office and construction)	Future	Soil ingestion Inhalation of indoor VOCs (office worker only) Inhalation of airborne particulates Dermal contact with soil External irradiation
On-site ecological researcher	Future	Soil ingestion Inhalation of airborne particulates Surface-water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface-water/suspended sediment External irradiation
Hypothetical off-site resident	Future	Soil ingestion Ingestion of vegetables (surface deposition of particulates) Inhalation of airborne particulates Surface-water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface-water/suspended sediment

TABLE 2-1
(continued)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Hypothetical on-site resident	Future	Soil ingestion Ingestion of vegetables (uptake and surface deposition of particulates) Inhalation of airborne particulates Surface-water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface-water/suspended sediment Inhalation of indoor VOCs Groundwater ingestion External irradiation



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

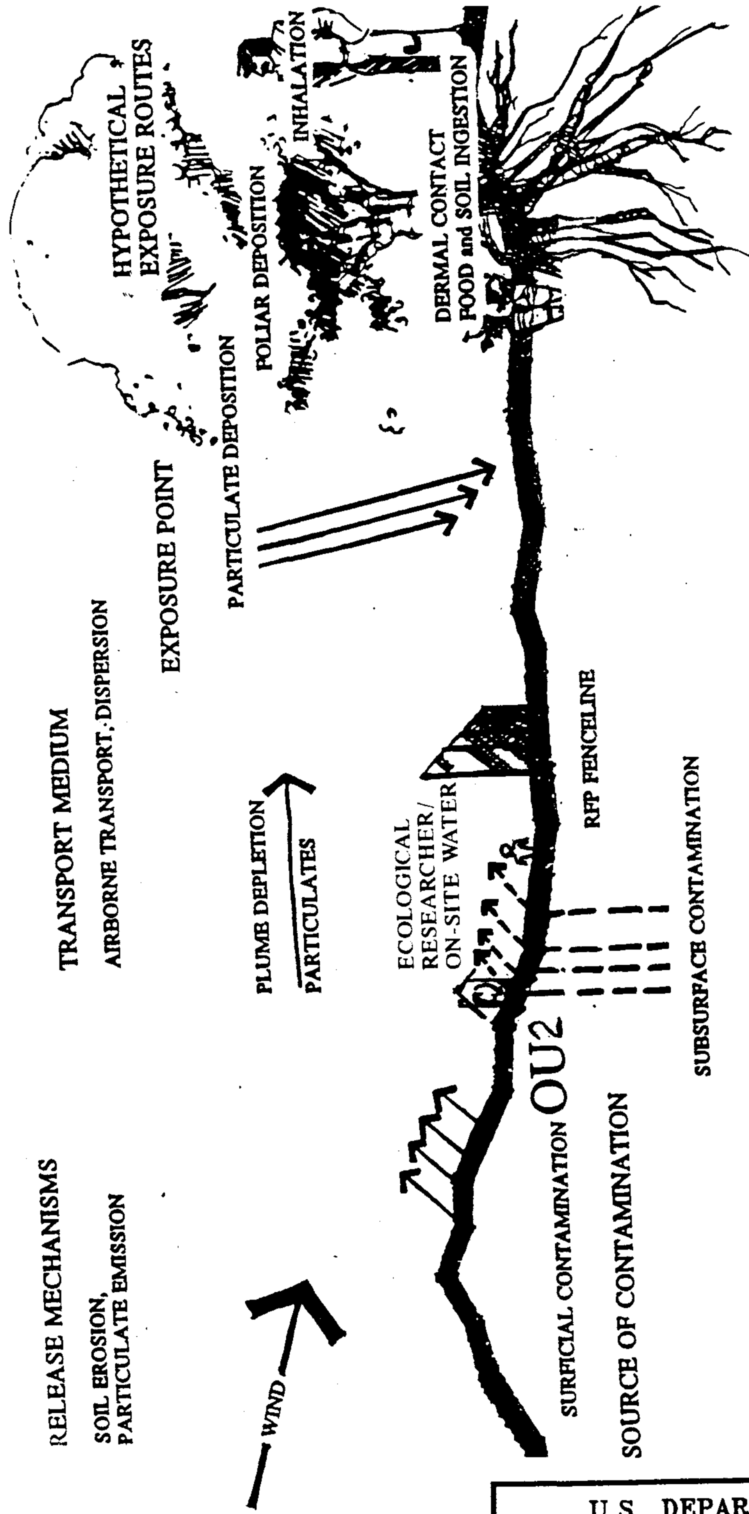
OPERABLE UNIT NO. 2
PHASE II RFI/RI MODELING
TECHNICAL MEMORANDUM

SURFACE-WATER CONCEPTUAL MODEL

FIGURE 2-4

JULY, 1992

R3302.2-1



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI MODELING
TECHNICAL MEMORANDUM

CONCEPTUAL MODEL FOR
AIRBORNE EXPOSURE PATHWAYS

FIGURE 2-5

8/21/92

3.0
MODEL DESCRIPTION

This section specifies the models to be used in characterizing and predicting exposure point concentrations at specific receptor locations for the OU-2 risk assessment. The considerations for model selection, and the basis for selecting the chosen models are also discussed.

The term "model" refers to computer codes or a set of equations that can be used to mathematically represent site conditions and simulate media behavior (e.g., groundwater flow) and contaminant fate and transport in the model domain. The models will incorporate site-specific data to allow simulation of site-specific conditions and behavior. The combination of a computer code and the necessary site-specific data will be referred to as a "site-specific model".

3.1 GENERAL CONSIDERATIONS FOR MODEL SELECTION

According to Bond and Hwang (1988) and van der Heijde and Park (1986), the following issues should be considered when selecting groundwater models for simulating conditions at a site: (1) the objectives of the project, (2) the physical and chemical conditions of the site, and (3) the requirements for implementing the models. Although the discussions presented by Bond and Hwang, and van der Heijde and Park were directed at groundwater models, it is reasonable to apply the same considerations to surface-water and air models.

The OU-2 modeling objectives (issue no. 1) are to simulate the transport of contaminants of concern for risk assessment purposes and to support the evaluation of remedial alternatives for the Feasibility Study. The physical and chemical conditions of the site (issue no. 2) have been and are continuing to be characterized as part of the ongoing RFI/RI process. Models selected should be capable of incorporating key onsite transport processes. Models should also be capable of accurately representing the hydrogeologic characteristics including the variability of media properties at the site as defined by the RFI/RI. Requirements for implementing the models (issue no. 3) include the following: (a) the availability of the model, (b) the degree and nature of documentation, (c) the extent of peer review of the model, and (d) the nature of model verification and testing (model verification is the process of verifying that the model results are numerically correct and involves an independent check of the calculations performed by the model).

Based on the issues described above, a set of criteria was developed for selecting the models to be used at OU-2. The general criteria are as follows:

1. The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.
2. The selected models should be able to satisfy the objectives of the study.
3. The selected models should be verified using published equations and solutions.
4. The selected models should be complete and well documented and preferably available in the public domain.
5. The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

These five criteria were used as the basis for selecting the groundwater, surface-water, and air models to be used for OU-2. The following sections discuss the selected models relative to their ability to satisfy the identified selection criteria.

All mathematical models have limitations and uncertainties associated with assumptions inherent in the models. This is true for the models selected for use for OU-2. However, it is believed that the selected models presented herein are the most appropriate models available for use for OU-2 and that the associated limitations and uncertainties are acceptable.

3.2 GROUNDWATER FLOW MODEL

3.2.1 Introduction

Groundwater flow modeling will be performed for use as input to the groundwater contaminant fate and transport model in support of the OU-2 Human Health Risk Assessment, and for use in the OU-2 Feasibility Study. Available hydrologic and geologic information will be integrated to aid in understanding and quantifying the groundwater flow system within the UHSU. Because of the complexity of the groundwater flow system within the Rocky Flats Alluvium and Arapahoe Formation No. 1 Sandstone of the UHSU, and the need for the model to support the OU-2 Human Health Risk Assessment and Feasibility Study, a three-dimensional numerical groundwater flow model has been selected. The numerical flow model that will be used is the USGS modular three-dimensional groundwater flow model MODFLOW (McDonald &

Harbaugh 1988). Specifically, the groundwater flow model will be used to simulate saturated groundwater flow in the Rocky Flats Alluvium and No. 1 Sandstone portions of the UHSU in the OU-2 area and will provide hydraulic head distributions over the model domain. The hydraulic head distribution from the MODFLOW output will serve as input to the contaminant fate and transport model for that domain (see Section 3.3) that will be used, in conjunction with other models, to estimate concentrations of chemicals of concern at exposure points for potential human receptors. Additionally, the MODFLOW model can be used to simulate potential remediation strategies, if necessary, as part of the OU-2 Feasibility Study.

3.2.2 Model Selection Criteria Evaluation

The MODFLOW model was selected because it is believed to best satisfy the five selection criteria presented above. A discussion of how MODFLOW meets each of these criteria follows in the order in which the selection criteria are presented in Section 3.1.

<u>Selection Criterion No. 1</u> - The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The MODFLOW model is capable of incorporating key processes and representing the conditions known to occur at the site. These include saturated porous media flow; the spatial (horizontal and vertical) distribution of hydrostratigraphic units (i.e., the Rocky Flats Alluvium, No. 1 Sandstone, and claystone); the spatial distribution of hydraulic parameters for the geologic materials present at the site (i.e., hydraulic conductivity and storage term); the spatial distribution and temporal variation of groundwater levels in the UHSU; the influence of hydraulic inputs and outputs to the system (such as recharge from precipitation), and hydraulic boundary conditions (i.e., groundwater inflow, and outflow to seeps).

One of MODFLOW's strongest attributes is its ability to integrate complex hydraulic and hydrogeologic data into a comprehensive model that can be used to aid in understanding and quantifying the groundwater flow system. MODFLOW's ability to simultaneously deal with complex hydrogeologic conditions, complex hydraulic boundaries, multiple hydraulic inputs and outputs to the system, and temporally variable conditions makes it valuable for characterizing the site groundwater flow system. The output from MODFLOW is a detailed hydraulic head map that can be used as input to other models to simulate groundwater flow directions and velocities, and contaminant fate and transport behavior.

Selection Criterion No. 2 - The selected models should be able to satisfy the objectives of the study.

MODFLOW is capable of satisfying the objectives listed in Section 1.1. Although MODFLOW is a groundwater flow model and is not used to simulate contaminant fate and transport or predict future concentrations of chemical contaminants, the output from the site-specific MODFLOW flow model supports the risk assessment because it provides the input for the contaminant fate and transport model that does predict exposure point concentrations. Because MODFLOW allows simulation of a detailed groundwater flow field, it can be used in conjunction with many contaminant fate and transport models.

Following development of the site-specific baseline groundwater flow model (i.e., the model that simulates present conditions), the site-specific MODFLOW model can be used as a predictive model to simulate changes in the groundwater flow system in response to changes in inputs and outputs to the system. As such, it is particularly useful for evaluating the potential effectiveness of potential remediation systems (e.g., pumping wells, collection trenches). Therefore, a detailed flow model like MODFLOW is particularly useful in support of feasibility study activities.

Selection Criteria 3 and 4 - The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

MODFLOW is a widely used and well-documented finite-difference groundwater flow model supported by the USGS and accepted by EPA, which has been successfully applied to many complex flow problems. MODFLOW is documented in a comprehensive manual prepared by the USGS (McDonald and Harbough 1988), which documents the model theory and program structure; provides instructions for model use; and presents a listing and narrative of the model code. Verification of MODFLOW has been performed by the developers (USGS) and independent users using published analytical solutions to the partial-differential equation for groundwater flow through porous media. MODFLOW is a public domain code that is readily available. A copy of the MODFLOW source code is provided with the purchase of MODFLOW.

Selection Criterion 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

MODFLOW can be practically and cost-effectively applied to the OU-2 site. MODFLOW is designed for ease of use. Gridding and model set-up can be performed easily, and MODFLOW's modular structure makes adding or deleting input/output modules simple. Therefore, subsequent modifications to the model (e.g., adding pumping wells to evaluate a possible remediation system) are easily accomplished.

The output from the MODFLOW simulations can readily be used to address resolution of uncertainty.

3.3 GROUNDWATER CONTAMINANT FATE AND TRANSPORT MODEL FOR ALLUVIUM AND NO. 1 SANDSTONE

3.3.1 Introduction

Groundwater contaminant fate and transport modeling will be performed to simulate the movement of dissolved contaminants in groundwater in the saturated zone beneath OU-2, and to estimate future dissolved contaminant concentrations in groundwater at identified discharge points. This will allow the evaluation of contaminant transport to potential human receptors in the OU-2 Human Health Risk Assessment.

Because of the spatial and temporal complexity of the groundwater flow system within the Rocky Flats Alluvium and Arapahoe Formation No. 1 Sandstone of the UHSU, and the numerous sources present in OU-2, it is believed that a numerical model should be used to simulate contaminant fate and transport in the Rocky Flats Alluvium and No. 1 Sandstone at OU-2. The model that has been selected is the modular three-dimensional contaminant fate and transport model MT3D (Zheng 1990). MT3D is similar in structure to MODFLOW and can incorporate MODFLOW output directly. MT3D simulates the processes of advection, dispersion, sink/source mixing, and chemical reactions.

Available data on fate and transport parameters (e.g., chemical decay and dispersivity), source areas and behavior, and the nature and extent of groundwater contamination will be integrated with the MODFLOW groundwater flow data to simulate the fate and transport of dissolved phase contaminants with MT3D. Specifically, the site-specific MT3D model will be used to simulate existing groundwater contamination conditions and to estimate future contaminant concentrations at groundwater discharge points. The results of the site-specific MT3D model will then be used as inputs to the colluvium groundwater model, or the surface-water model which will simulate the movement of contaminants to the receptor points.

3.3.2 Model Selection Criteria Evaluation

The MT3D model was selected from a number of available contaminant fate and transport models because it is believed to best satisfy the selection criteria presented in Section 3.1 above. A discussion of how MT3D meets each of these criteria follows in the order in which the selection criteria are presented in Section 3.1.

Selection Criterion No. 1 - The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The MT3D model is capable of incorporating key contaminant fate and transport processes known to occur at the site. Those key processes include complex advection, dispersion, retardation, and decay processes. The MT3D model is also capable of representing the complex conditions that occur onsite. These include the potential spatial (horizontal and vertical) distribution of fate and transport parameters (such as retardation and dispersion coefficients); the influence of boundary conditions; the spatial and temporal variations of chemical contaminant concentrations in the UHSU; and the spatial distribution and temporal behavior of multiple sources.

MT3D is capable of simulating the fate and transport of dissolved phase contaminants in the saturated portion of the UHSU. Modeling of the fate and transport of contaminants within the vadose zone (i.e., unsaturated zone) between the near-surface source areas (e.g., the trenches) and the saturated zone is not proposed because of the large uncertainties associated with the complex flow and transport processes in the vadose zone, and the limited technology currently available for vadose zone modeling. For the purposes of this study it will be assumed that migration pathways through the vadose zone have been fully established between the source areas and the water table and, thus, current concentrations of contaminants in the saturated zone beneath the source areas are equal to or greater than what will occur at those locations in the future. This is believed to be a reasonable assumption given that the source areas have been in existence for 20 to 30 years.

Transport of contaminants in the saturated zone via colloidal processes is not proposed because current modeling technology for colloidal transport is limited to the research arena, and has not been widely applied or accepted. It is believed that simulation of dissolved phase contaminants with MT3D is adequate and conservative because those contaminants are likely to be more mobile than colloidal phase contaminants in the saturated zone.

Selection Criterion No.2 - The selected models should be able to satisfy the objectives of the study.

MT3D is capable of satisfying the applicable objectives listed in Section 1.1. Output from the site-specific MODFLOW groundwater flow model in the form of a groundwater flow field will serve as input to MT3D. MT3D will then be used to simulate the movement of dissolved chemical contaminants in groundwater through the saturated Rocky Flats Alluvium and No. 1 Sandstone of the UHSU and to estimate future concentrations of chemical contaminants at identified groundwater discharge points. Those results will then be used, in conjunction with the colluvium groundwater fate and transport model, to provide input to the surface-water model used to estimate concentrations of chemicals of concern at exposure points for potential human receptors in support of the OU-2 Human Health Risk Assessment.

The ability of MT3D to simulate the key contaminant fate and transport processes, and incorporate the heterogeneity of the transport parameters and the complex boundary and source conditions into a comprehensive fate and transport model, makes it well suited for use for this site. In addition to estimating future concentrations in support of the Human Health Risk Assessment, MT3D can be used to evaluate the effectiveness of potential remediation strategies on contaminant source control, or the prevention of further plume migration in support of the OU-2 Feasibility Study.

Selection Criteria No. 3 & 4 - The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

MT3D is a widely used and well-documented finite difference contaminant fate and transport model. It has been successfully applied to many complex groundwater contaminant fate and transport problems. MT3D is documented in a comprehensive manual that describes the model theory and program structure; provides instructions for use; and addresses verification and application of the model. Verification of MT3D using test problems for which analytical solutions are available has been performed by the developers and is documented in a section of the MT3D manual. MT3D is distributed by S.S. Papadopulos & Associates with the model source code and is readily available.

Selection Criterion No. 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

MT3D can be practically and cost-effectively applied to the OU-2 site. MT3D is designed in a structure similar to MODFLOW and is, therefore, easy to set-up and use. Using MT3D in conjunction with MODFLOW is advantageous because MT3D has been designed to directly take MODFLOW hydraulic head output data as MT3D input, eliminating the need for any intermediate data manipulation steps.

The output from the MT3D simulations can readily be used to address resolution of uncertainty.

3.4 GROUNDWATER CONTAMINANT FATE AND TRANSPORT MODEL FOR THE COLLUVIUM

3.4.1 Introduction

As discussed in Section 1.2.4, groundwater discharges at seeps and springs on the hillsides of OU-2, where the alluvium and No. 1 Sandstone outcrop or subcrop along the valleys of South Walnut and Woman Creeks. The water and any associated contaminants then migrate to the creeks via surface flow or near surface groundwater flow in the colluvium mantling the hillsides.

The model that has been selected for simulating contaminant fate and transport within the near surface groundwater in the colluvium is the analytical transport model ONED3 (Beljin 1989). ONED3 is included in the SOLUTE package of models distributed by the International Ground Water Modeling Center (IGWMC), and is capable of simulating one dimensional fate and transport of dissolved phase contaminants in a porous medium. Specifically, ONED3 will utilize the output from the MT3D model and will simulate the fate and transport of contaminants from the seeps and springs, through the colluvium, to South Walnut and Woman Creeks. The results of the site-specific ONED3 model will then be used as inputs to the surface-water model.

3.4.2 Model Selection Criteria Evaluation

The ONED3 model was selected because it is believed to satisfy the selection criteria presented in Section 3.1. A discussion of how ONED3 meets each of these criteria follows in the order in which the selection criteria are presented in Section 3.1.

Selection Criterion No. 1 - The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The ONED3 model is capable of incorporating key contaminant fate and transport processes known to occur in the colluvium at the site. Those key processes include advection, dispersion, retardation, and decay. The ONED3 model is capable of simulating fate and transport in a relatively simple groundwater flow system with simple boundary and source conditions. This is considered adequate for the colluvium because flow is primarily one directional (i.e., from the seeps and springs downslope to the creeks), the flow distance is relatively short (thus effects from variations in the groundwater velocity field and from areal recharge are probably small), and the flow boundary and contaminant source conditions are relatively simple.

Selection Criterion No. 2 - The selected models should be able to satisfy the objectives of the study.

ONED3 is capable of satisfying the applicable objectives listed in Section 1.1. Output from the site-specific MT3D model in the form of concentrations of contaminants in groundwater discharging at the seeps and springs will serve as input to ONED3. ONED3 will then be used to simulate the movement of dissolved chemical contaminants in groundwater in the colluvium and to estimate future concentrations of chemical contaminants where groundwater discharges to South Walnut and Woman Creeks. This will then serve as input to the surface-water model used to estimate concentrations of chemicals of concern at exposure points for potential human receptors in support of the OU-2 Human Health Risk Assessment.

ONED3 can be used in conjunction with the MT3D fate and transport model to evaluate the effects of potential remediation strategies implemented for contaminant source control or plume migration on contaminant concentrations discharging from the colluvium to the creeks. In this way, ONED3 can be used to support the OU-2 Feasibility Study.

Selection Criteria No. 3 & 4 - The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

ONED3 is a widely used and well-documented analytical contaminant fate and transport model. Verification is easily performed using published analytical equations. ONED3, as part of the SOLUTE package of models distributed by IGWMC, is readily available with complete documentation.

Selection Criterion No. 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

ONED3 can be practically and cost-effectively applied to the OU-2 site. ONED3 is straightforward to set-up and use. The output from the ONED3 simulations can readily be used to address resolution of uncertainty.

3.5 SURFACE-WATER MODEL

3.5.1 Introduction

The surface-water model will contribute to the overall risk assessment effort by means of several exposure pathways, as shown in Figure 2-2. The surface-water model will accept as input stormwater runoff, surface discharge of groundwater (seep flow), and contaminant loads from stormwater runoff and seep flow.

Long-term average concentrations of the contaminants of concern in Woman and South Walnut Creeks are of interest. The surface-water model for a given contaminant in either Woman or South Walnut Creek is given by the mass balance (dilution) equation:

$$\text{Average Annual Concentration} = \frac{\text{Total Annual Groundwater Load} + \text{Total Annual NPS Load}}{\text{Total Annual Streamflow}} \quad (1)$$

The Total Annual Groundwater Load represents contaminant loads entering Woman or South Walnut Creeks from groundwater springs and seeps; the Total Annual Nonpoint Source (NPS) Load represents that contaminant load entering Woman and South Walnut Creeks from surface-water runoff; and the Total Annual Streamflow is the streamflow available for transport and dilution of these contaminant loads.

The Total Annual Groundwater Load will be the output of the groundwater modeling activities discussed above. Discussion of proposed estimation techniques for the Annual Total NPS Load and Annual Total Streamflow follow.

Soil Erosion Model

The Total Annual NPS Load will be estimated from an empirical relationship, the Universal Soil Loss Equation (USLE). This equation was developed to predict soil loss due to sheet and rill surface flow from statistical analysis of over 10,000 plot-years of erosion field research data (Wischmeier and Smith 1978). The USLE will estimate the annual soil loss (tons/year) due to sheet and rill erosion. From that sediment load, the corresponding contaminant load will be estimated using measured OU-2 soil concentrations.

The USLE is

$$S = RKLC \tag{2}$$

where

S	=	Rate of soil loss ($M/L^2/T$)
R	=	Rainfall/runoff erosivity factor (dimensionless)
K	=	Soil erodibility factor (dimensionless)
L	=	Length-slope factor (dimensionless)
C	=	Cover/management factor (dimensionless)

The rainfall/runoff erosivity factor R is a measure of rainfall intensity. Average annual values for the United States have been computed by Wischmeier and Smith (1978). Alternatively, R can be determined for an individual storm event by the equation

$$R = EI_{30}/100 \tag{3}$$

where

E = Total kinetic energy of a storm (LM/L^2)
I_{30} = Maximum 30-minute intensity of the storm (L/T)

An alternative method to the Wischmeier and Smith data referenced above for determination of an average annual R is use of the 2-year, 6-hour storm in equation (3) (Barfield et al. 1981).

The soil erodibility factor K is an experimentally derived coefficient for a specified soil. K is measured on a unit plot of soil defined as 72.6 feet in length and having a 9 percent slope in uniformly smoothly tilled soil. For situations where experimental plot data are not available, a nomograph can be used that utilizes soil structure, textural parameters, and percent organic matter (Barfield et al. 1981). The USDA Soil Conservation Service (SCS) has developed K values as a function of soil texture in the vicinity of OU-2 (Price and Amen 1983).

The length-slope factor L is the ratio of soil loss from the average field length and slope to that from a 72.6 foot long, 9 percent slope under otherwise identical conditions. It is defined as the distance from the point of origin of overland flow to the point that the slope decreases such that deposition occurs or until the flow enters a defined channel. Wischmeier and Smith (1978) proposed that the L factor can be estimated by

$$L = (0.045x)^b(65.41\sin^2(\Theta) + 4.56\sin(\Theta) + 0.065) \qquad (4)$$

where

x = Slope length (m)
Θ = slope inclination (degrees)
b = 0.2 - 0.5, depending on x

Research data support equation (4) for $x \leq 100$ m and $\Theta \leq 10.2$ degrees, although in practice, it is often applied beyond these limits (EPA 1985). A nomograph for L has been generated by the SCS using this equation.

The cover/management factor C describes the protection of the soil surface by plant canopy, crop residues, mulches, etc. The maximum C value is 1.0, corresponding to no protection.

Generalized annual values for C have been determined for permanent pasture, range, and idle land (Wischmeier and Smith 1978).

Rainfall/Runoff Model

Estimation of the Total Annual Streamflow will occur either directly, by analysis of historical streamflow data, or by modeling, using empirical methods developed by the SCS. The SCS curve number equation (CNE) (USDA 1986) method is a standard procedure for estimating runoff (Mockus 1972; Ogrosky and Mockus 1964). The CNE estimates runoff as a function of precipitation and a water detention parameter as

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \text{ for } P \geq 0.2S \tag{5}$$

where

Q = runoff (in)
P = precipitation (rainfall+snowmelt, in)
S = water retention parameter (in)

The retention parameter S is computed from "curve numbers" (CNs), which are determined as a function of soils, cover, management practices, and antecedent moisture. The term, 0.2S, is an initial precipitation abstraction such that, if $P < 0.2S$, Q is assumed to be zero. The relationship between S and CN is

$$S = 1000/CN - 10 \tag{6}$$

The CN is a dimensionless parameter that ranges in value from 10 to 100. As can be seen from equations (5) and (6), runoff increases with increasing CN, attaining a maximum, i.e. all precipitation becomes runoff, such as from an impervious parking lot, at CN=100.

Although the CN method has most often been applied only to rainfall runoff, it may be used for snowmelt conditions (EPA 1985). Snowmelt water can be estimated by the degree-day equation

$$M = 0.45T \tag{7}$$

where

M	=	snowmelt water (cm)
T	=	mean air temperature (°C)

If $T < 0$, then $M = 0$. Also, M must not exceed the water content of the accumulated snowpack.

3.5.2 Model Selection Criteria Evaluation

The surface-water models described above were selected because they are believed to best satisfy the five selection criteria presented above. A discussion of how these models meet each of these criteria follows in the order in which the selection criteria are presented in Section 3.1.

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

Key processes associated with surface-water aspects of OU-2 include soil washoff/erosion and surface runoff from precipitation events. Soil washoff/erosion will be incorporated by means of the USLE while surface runoff will be estimated either directly from historical streamflow data, or indirectly by modeling using the SCS Curve Number method.

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study.

The selected surface-water models meet the modeling objectives discussed in Section 1.1. To support the risk assessment objective, the selected models can simulate the transport of chemicals of concern from sources (stormwater runoff, groundwater discharge) to downstream exposure points. To support the feasibility study, the models provide the flexibility needed to estimate risks posed by individual sources, i.e. the risks associated with either stormwater runoff only or groundwater discharge only.

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

Both the USLE and the SCS CNE are widely used and accepted within the surface-water hydrology field. The USLE was developed and originally discussed by Wischmeier and Smith (1978). A more recent discussion is provided in an EPA water quality assessment guidance manual (EPA 1985). The SCS CNE method is described in the report, "Urban Hydrology for Small Watersheds" (USDA 1986). The CNE method has been coded in a number of available computer programs, including QUICK TR-55 and TR-20 (HAESTAD 1991). The mass balance method is also widely accepted in the field of environmental engineering.

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The USLE and the SCS CNE methods are essentially *empirical* models that involve relatively few parameters. Their empirical nature ensures that they are practical methods because of the extensive databases on which they are based. In addition, because few parameters are involved, calibration of these models to OU-2 data will be cost-effective.

3.6 SOIL GAS TRANSPORT MODEL

3.6.1 Introduction

Soil gas transport modeling will be performed to simulate the diffusion of volatile organic compounds from underlying soil gas as a result of volatilization from soil and UHSU groundwater contaminants to the OU-2 surface just beneath a hypothetical on-site building. An air transport and dispersion model, discussed in Section 3.7, will then be used to estimate airborne VOC concentrations within the building. This activity will support and provide input to a Human Health Risk Assessment.

Estimates of volatilization from underlying contaminated soil closest to the OU-2 surface will be provided by utilization of the Shen Model, modified by Farino (Farino et. al., 1983), from

Volume II of the Air/Superfund National Technical Guidance Series published by the EPA (EPA, 1990). This model is also referred to as the SEAM model, since it is also documented in the Superfund Exposure Assessment Manual (SEAM) (EPA, 1988a). This equation is designed for estimating volatilization from underlying soil contamination and the subsequent diffusion of organic vapors to the OU-2 surface. This equation has been applied in numerous site investigations and has been validated enough to warrant inclusion in published EPA documents.

The equation used to estimate the steady-state VOC emission rate is as follows:

$$E_i = (AD_i/L)(P_t^{4/3})(C_i)(W_i) \qquad (1)$$

where E_i = emission rate of the contaminant, i (g/sec);
A = surface area (cm^2);
D_i = vapor diffusion coefficient in air (cm^2/sec);
L = surface cap thickness (cm);
P_t = total porosity of the soil cap (cm^3/cm^3);
C_i = saturated vapor concentration of contaminant, i, in the vapor space beneath the surface soil cap (g/cm^3); and
W_i = weight fraction of contaminant, i, in the waste (g/g).

C_i, the saturated vapor concentration, is defined by the equation:

$$C_i = \frac{PMW_i}{RT} \qquad (2)$$

where P = vapor pressure of the contaminant (mm Hg)
MW_i = molecular weight of the contaminant (gm/gm-mole)
R = molecular gas constant (62,361 mm Hg-cm^3/gm-mole-°K)
T = ambient temperature (°K)

Contributions to surface volatilization emissions from the underlying UHSU groundwater will be estimated by the using the following equation, adapted from Thibodeaux and Hwang (1982), as presented in SEAM:

$$E_{i(t)} = 2DC_sA/(d + ((2DC_st/C_b) + d^2)^{0.5}) \qquad (3)$$

where $E_{i(t)}$ = average emission rate of contaminant i over time t (g/sec)
D = phase transfer coefficient (cm^2/sec)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm^3)
C_b = bulk contaminant i concentration in the soil (g/cm^3)
A = contaminated surface area (cm^2)
d = depth of the dry zone at sampling time (cm)
t = time measured from sampling time (sec)

This equation assumes that the soil pore spaces connect with the soil surface, the soil conditions are isothermal and that there is no capillary rise of contaminant. In addition, sufficient liquid contaminant in the pore spaces is assumed to exist so that volatilization will not deplete the reservoir of contaminant to the point where the rate of volatilization is affected. Use of this equation simulates vapor diffusion as being soil-phase controlled and assumes that contaminant concentrations in the soil remain constant until all contaminant is volatilized to the ambient air at the surface. Contaminant release is assumed to occur by the "peeling away" of successive unimolecular layers of contaminant from the surface of the "wet" contaminated zone. Thus, over time, a "dry zone" of increasing depth at the soil surface and a wet zone of decreasing depth below the dry zone develops. Concentrations of the contaminant in the soil immediately surrounding the groundwater areas and within the groundwater are used in this estimation method.

The term, D, in the above equation is related to the amount of contaminant i that transfers from the liquid to gas phases and then from the gas phase to diffusion in the surface air and is estimated by:

$$D = D_i(P_t^{4/3})\ H_i' \qquad (4)$$

where D_i = vapor diffusion coefficient in air (cm^2/sec)
P_t = total soil porosity (dimensionless)
H_i' = Henry's Law constant in concentration form (dimensionless)

Finally, the term, H_i', is estimated by the below equation:

$$H_i' = H_i / RT \qquad (5)$$

where H_i = Henry's Law constant of the contaminant i (atm-m^3/g-mole)
R = gas constant (8.2×10^{-5} atm-m^3/g-mole-°K)
T = atmospheric temperature (°K)

The Thibodeaux and Hwang equation assumes that the contaminant concentration in the liquid and gas phases in the soil remains constant until all of the contaminant has been volatilized into the surface ambient air. The emission rate, $E_{i(t)}$, is non-zero until the time, t, is equal to a value, t_d, when the soil becomes dry and all contaminant has been volatilized. After time t_d, the volatilization emission rate is assumed to be zero. The estimation of t_d, in seconds, is obtained from the below equation:

$$t_d = ((h^2 - d^2)/2D)(C_b/C_s) \qquad (6)$$

where h = depth from the surface to the bottom of the UHSU layer (cm)
d = depth of dry zone at sampling time (cm)
D = phase transfer coefficient (cm^2/sec)
C_b = bulk contaminant i concentration in soil (g/cm^3)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm^3)

Total surface volatilization emissions are then estimated by adding the contributions calculated from Equations (1) and (3). To estimate the diffusion of surface volatilization emissions through the floor of an on-site building, Darcy's law, modified for gas flow across a permeable structure wall, will be used to estimate the volumetric flow rate induced by surface volatile emissions and ambient air entering into the building confines. This volumetric flow rate is estimated by:

$$Q_{vol} = -k\ A/v\ (dP/dZ) \qquad (7)$$

where Q_{vol} = volumetric flow rate induced by soil gas and ambient air
k = intrinsic permeability of soil
v = viscosity of the gas
dP = pressure differential across floor of structure
dZ = thickness of floor

The concentration of the contaminant within the on-site building is then estimated by:

$$C_{con} = E_i \;/\; Q_{vol} + Q_b \tag{8}$$

where C_{con} = resultant contaminant concentration within the building
E_i = emission rate of the contaminant below the building floor
Q_{vol} = volumetric flow rate induced by the soil gas
Q_b = volumetric exchange rate within the building

3.6.2 Model Selection Criteria Evaluation

A considerable amount of research and field sampling has been performed to develop models that predict volatilization as a result of soil gas transport. The SEAM models were selected because they are believed to best satisfy the selection criteria defined in Section 3.1.

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The SEAM models are capable of representing key contaminant processes in estimating soil gas transport. The key processes in the SEAM models include treatment of soil gas diffusion to the surface as a result of underlying soil contamination and also the diffusion from areas of soil and groundwater contamination. The models allow calculation of volatilization of specific components of a complete waste mixture by assuming that Raoult's Law is applicable. A layer of relatively clean and dry soil is assumed to exist between the soil surface and the primary area of underlying soil contamination for the first SEAM equation (Equation (1)). The depth of this relatively clean layer will be assessed by examining site-specific data. Equation (1) assumes that surface VOC emissions are steady-state and do not decay with time. This assumption is consistent with site observations that there are underlying areas of soil contamination likely to produce surface VOC emissions at a steady rate for an extended period of time. Surface VOC emission contributions from the UHSU groundwater (Equation (3) exhibit some dependency with time but will probably not change total surface VOC emissions from a nearly steady state condition.

Examination of on-site data suggests that volatilization as a result of soil gas transport will primarily originate from underlying soil contamination areas closest to the OU-2 surface and from the underlying UHSU groundwater.

<u>Selection Criterion 2</u> -- The selected models should be able to satisfy the objectives of the study.

The SEAM models estimate surface volatilization from underlying soil gas with consideration of physical and chemical mechanisms. The resulting emission estimates can then be applied to the estimation of exposure point concentrations.

Since air contaminant concentrations are directly proportional to emissions estimates, the effectiveness of potential remediation strategies on sources of volatilization that become part of the air exposure pathways can be readily evaluated. In addition, the effectiveness of potential remediation strategies can be related to underlying soil and groundwater concentrations since these soil gas transport models estimate VOC emissions in nearly direct proportion to underlying soil (waste) and groundwater concentrations.

<u>Selection Criteria 3 and 4</u> -- The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

The SEAM models for soil gas transport are widely used and well-documented in EPA literature for use in baseline, remedial and post-remedial scenarios. Equation (1) has refined the widely accepted Farmer model which was one of the first models developed and used to predict VOC emissions from covered landfills. Equation (3) has been widely used for estimation of surface volatilization emissions from old spills and leaks that have migrated below the soil surface. The soil gas transport models appearing in the air pathway analysis series have been subject to extensive validation.

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

These soil gas transport models thoroughly document the proper use of input parameters and demonstrates their use through simulated soil gas transport scenarios. Thus, these models can be easily placed into a spreadsheet format to handle multiple volatile organic compounds. Since these models are public domain, there are no procurement or licensing costs for their use.

3.7 AIR TRANSPORT AND DISPERSION MODELS

3.7.1 Introduction

Air dispersion models simulate the transport of the ambient air volatilization rates estimated from the soil gas transport model and particulate matter to specific exposure points for the air exposure pathways designated in Section 2.0. Two different air dispersion models will be utilized according to the following scenarios:

- The transport of volatile organic compounds into a building located on the surface of OU-2.

- The transport of particulate matter to on-site receptors both as air contaminant concentrations and air deposition values.

- The transport of particulate matter to off-site receptors (i.e., future and current off-site resident) both as air contaminant concentrations and air deposition values.

The air contaminant concentration and deposition values provided by these air transport models will support and provide input to the Human Health Risk Assessment. The model for on-site receptors will be a conventional box model that is used widely for immediate exposure scenarios. The models for off-site receptors will be based on Gaussian dispersion and are models approved by EPA. Both models will provide ambient air contaminant concentration and deposition values at the previously defined exposure points.

3.7.2 Model Selection Criteria Evaluation

The models selected to be most appropriate for OU-2 are a conventional box model for on-site impacts and the Fugitive Dust Model (FDM) for estimation of airborne particulate concentrations and deposition at off-site receptor locations. These models are believed to best satisfy the selection criteria presented in Section 3.1. A box model will be used to model transport of volatiles to an on-site worker in an industrial building, and will also be used to model ambient particulate impacts to a future industrial worker and to a future ecological worker also located on-site. The FDM will be used to model transport of airborne particulate, both as air contaminant concentrations and as deposition values, at the current and future resident exposure points. A discussion of how each air transport model meets each of these criteria is presented below.

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The box model and the FDM air models are capable of representing key contaminant processes in estimating air transport and dispersion of air emissions originating from OU-2. The box model uses conservation of mass principles to estimate resultant air concentrations for an input emission rate dispersed within a fixed volume with an air exchange rate proportional to the air flow (wind speed) traversing the volume. The box model used for estimating on-site impacts considers the dilution of air emissions within a given volume, defined by the horizontal dimensions of a contaminated area or of an enclosed structure (i.e., building) and the height determined either by surface turbulence or the confined height of a structure. The air exchange rate is dependent upon the utilized wind speed or volumetric air exchange rate, if within the confines of a building. The FDM uses Gaussian plume transport and dispersion algorithms with a gradient-transfer deposition and settling algorithm to simulate air contaminant concentration and deposition values from non-point sources at distances corresponding to off-site receptors. The FDM was specifically developed for fugitive particulate matter modeling applications (especially wind erosion). The FDM has the capability of assessing up to 100 area sources, 200 receptor points, and 20 particle size classes. FDM is unique in that it can assess rectangularly shaped area sources, not just square or circular. This capability allows FDM to model area sources using a geometry that more closely approximates their actual shape. FDM can utilize constant as well as variable emission rates. FDM can also calculate ground-level concentrations either with settling and deposition functions (as with particulate matter), or without (as with gaseous contaminants). The FDM has the capability to model for short (1-, 3-, 8-, and 24-hour) and long (annual) term averaging periods, and uses meteorological data in either hourly or STability ARray (STAR) formats.

By using the AP-42 (EPA, 1988c) emission models (EPA 1988c) for fugitive particulate emission estimation, the FDM model is not required to apply correction factors to account for varying types of land surfaces. However, the FDM will allow for the direct computation of the contaminant emission rate as a function of the wind speed or allow the user to input a constant emission rate. In this way, the model can assess short-term and long-term impacts.

Receptor locations are evaluated by their relative distance (x,y) from the source and their elevation (z). (EPA 1988b).

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study.

Output from these models either as air contaminant concentrations or as deposition values at the designated exposure points will provide input for the assessment of human health risks. The ability of these models to simulate the transport and dispersion of particulate and radionuclides in particulate form supports the objective of the modeling effort.

The multiple compounds potentially identified as contaminants of concern will be easily handled by the selected air dispersion models through a multiplicative factor (the ratio of a specific compound source term to a unit emission rate) that is multiplied by the estimated ambient impacts from a unit emission rate (i.e., because of the linear relationship of air concentration to input emission rate). In addition, each of these models can be used to evaluate the effectiveness of potential remediation strategies by simply varying the source term as a function of the remediation strategy being examined.

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

Both models are recommended by EPA as the most representative methods for determining the respective transport and dispersion characteristics for VOCs and inorganic metals, semi-volatiles and radionuclides in particulate form. These models have been used extensively on both non-remedial and remedial studies (the FDM model has undergone considerable validation and verification).

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

Both models are readily available since they are public domain models and do not require special procurement or licensing costs. Their use is well-documented and both models are designed to execute on PC-compatible computers. Support for use of these models is also readily available. Their relative ease of use and wide acceptance of the modeling results makes them preferable over other available models.

3.8 SUMMARY OF PARAMETER VALUES

This section presents a summary of the data currently available to estimate model parameter values for groundwater, surface-water, and air modeling. Where available, site-specific data collected during the Phase I and II RFI/RI investigations or earlier studies will be used. If site-specific data are not available, published literature values will be used in the modeling activities. At present, only a portion of the Phase II RFI/RI soil and groundwater data are available. Additional site-specific data from the Phase II RFI/RI investigations will be utilized once those data become available.

Tables 3-1, 3-2, 3-3, and 3-4 present a summary of data currently available to estimate model parameters. The available data were compiled based on a review of previous investigations and the data currently available from the Phase II RFI/RI investigation, or general literature. In the case of chemical parameter values, development of the list of contaminants of concern (COCs) has not been completed at this time. Therefore, it is not possible to summarize chemical parameter data for each of the COCs at this time. Chemical parameter data will be compiled following EPA approval of the COC technical memorandum to be submitted later.

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site specific. The data values or ranges of values are not intended to be fixed or final. The ranges are presented to convey what is currently known of the potential variability in parameter values that may be used in the models.

TABLE 3-1
PARAMETER VALUES FOR GROUNDWATER MODELING

Parameter	Units	Range of Values	Source
Properties of Colluvium/Alluvium			
Hydraulic Conductivity	cm/sec	10^{-5} - 10^{-3}	Freeze and Cherry (1979) and OU-2 site-specific data
Storage Term	----	0.1 - 0.30	Freeze and Cherry (1979) and OU-2 site-specific data
Porosity	%	25 - 50	Freeze and Cherry (1979) and OU-2 site-specific data
Bulk Density	lbs/ft^3	94 - 130	Das (1985) and OU-2 site-specific data
Properties of Bedrock (Arapahoe No. 1 Sandstone)			
Hydraulic Conductivity	cm/sec	10^{-5} - 10^{-3}	Freeze and Cherry (1979) and OU-2 site-specific data
Storage Term	----	0.00005 - 0.30	Freeze and Cherry (1979) and OU-2 site-specific data
Porosity	%	5 - 30	Freeze and Cherry (1979) and OU-2 site-specific data
Bulk Density	lbs/ft^3	112 - 130	OU-2 site-specific data
Properties of Bedrock (Arapahoe Claystone)			
Hydraulic Conductivity	cm/sec	10^{-9} - 10^{-6}	Freeze and Cherry (1979) and OU-2 site-specific data
Storage Term	----	0.00005 - 0.30	Freeze and Cherry (1979) and OU-2 site-specific data
Primary Porosity	%	0 - 10	Freeze and Cherry (1979) and OU-2 site-specific data
Bulk Density	lbs/ft^3	101 - 120	OU-2 site-specific data

TABLE 3-2
PARAMETER VALUES FOR SURFACE-WATER MODELING

Parameter	Units	Range	Source
Rainfall/Runoff Erosivity Factor R	--	20 - 100	Wischmeier and Smith (1978)
Soil Erodibility Factor K	--	0.28 - 0.43	Price and Amen (1983)
Length-Slope Factor L	--	0.6 - 8.0	Barfield et al. (1981)
Cover/Management Factor C	--	0.01 - 0.36	Price and Amen (1983), Wischmeier and Smith (1978)
Curve Numbers CN	--	30 - 100	Price and Amen (1983), USDA (1986)

TABLE 3-3
PARAMETER VALUES FOR SOIL GAS MODELING

Parameter	Units	Range of Values	Source
Surface Area of IHSS	cm^2	10^6 - 10^{10}	Phase II RFI/RI Workplan (DOE 1991)
Surface Cap Thickness	cm	10^1 - 10^2	OU-2 site-specific data
Soil Cap Air-filled Porosity	%	25-35	OU-2 site-specific data
Vapor Diffusion Coeff. in Air	cm^2/sec	10^{-2} -10^{-1}	Compound-specific; SEAM (1988a) or Lyman (1982)
Thickness of contaminated soil	cm	10	OU-2 site-specific data
Weight fraction of contaminant in waste	g/g	10^{-9}-10^{-5}	OU-2 site-specific data; Trenches Areas RI Report
Intrinsic permeability of soil	cm^2	10^{-9}-10^{-7}	OU-2 site-specific data
Liquid-phase concentration of contaminant	g/cm^3	10^3-10°	OU-2 site-specific data

TABLE 3-4
PARAMETER VALUES FOR AIR TRANSPORT AND DISPERSION MODELING

Parameter	Units	Range of Values	Source
Joint frequency distribution of stability class, wind speed and direction	Unitless	fraction of one; total sum of all entries is one	RFP Site Environmental Report for 1990 (EG&G 1991a)
Mean annual morning and afternoon mixing heights	m	250-4000	Data for Denver, CO from Holzworth (1972)
Particle size	μm	1-80	OU-2 site-specific data
Particle size distribution	Unitless	fraction of one; total sum of all entries is one	OU-2 site-specific data
Contaminated area (surface dimensions)	m^2	10^3 - 10^4	OU-2 site-specific data
Ground Coverage	%	0-100	Aerial photos; on-site (unvegetated area) observations
Receptor location, above source, distance from source	m	$1\text{-}10^3$	Scaled maps of elevation of study area
Surface roughness	cm	1-100	Site observations correlated with documented criteria on assigning appropriate surface roughness value

4.0
SUMMARY

In order to model the fate and transport of contaminants at OU-2 to specific exposure point locations for the Human Health Risk Assessment, several models have been evaluated for application to groundwater, surface-water, and air modeling. Model selection was based on the following five criteria:

1. The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.
2. The selected models should be able to satisfy the objectives of the study.
3. The selected models should be verified using published equations and solutions.
4. The selected models should be complete and well documented and preferably available in the public domain.
5. The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The following models were selected to meet the requirements of the modeling study:

- The USGS MODFLOW numerical model for groundwater flow.
- The MT3D numerical model for groundwater contaminant fate and transport in the Rocky Flats Alluvium and Arapahoe Formation No. 1 Sandstone. The ONE3D analytical model for contaminant fate and transport in the colluvium.
- The Universal Soil Loss Equation, SCS Curve Number Equation, and Mass Balance Equation for surface-water fate and transport.
- The SEAM models for soil gas fate and transport, a box model for on-site ambient air contaminant fate and transport, and FDM for off-site ambient air contaminant fate and transport of OU-2 source air emissions.

Data currently available for use as input for the modeling activities were evaluated. Tables 3-1, 3-2, 3-3 and 3-4 summarize the data currently available to estimate model parameters. Additional data from the Phase II RFI/RI investigation may also be used in the modeling effort once those data become available.

5.0
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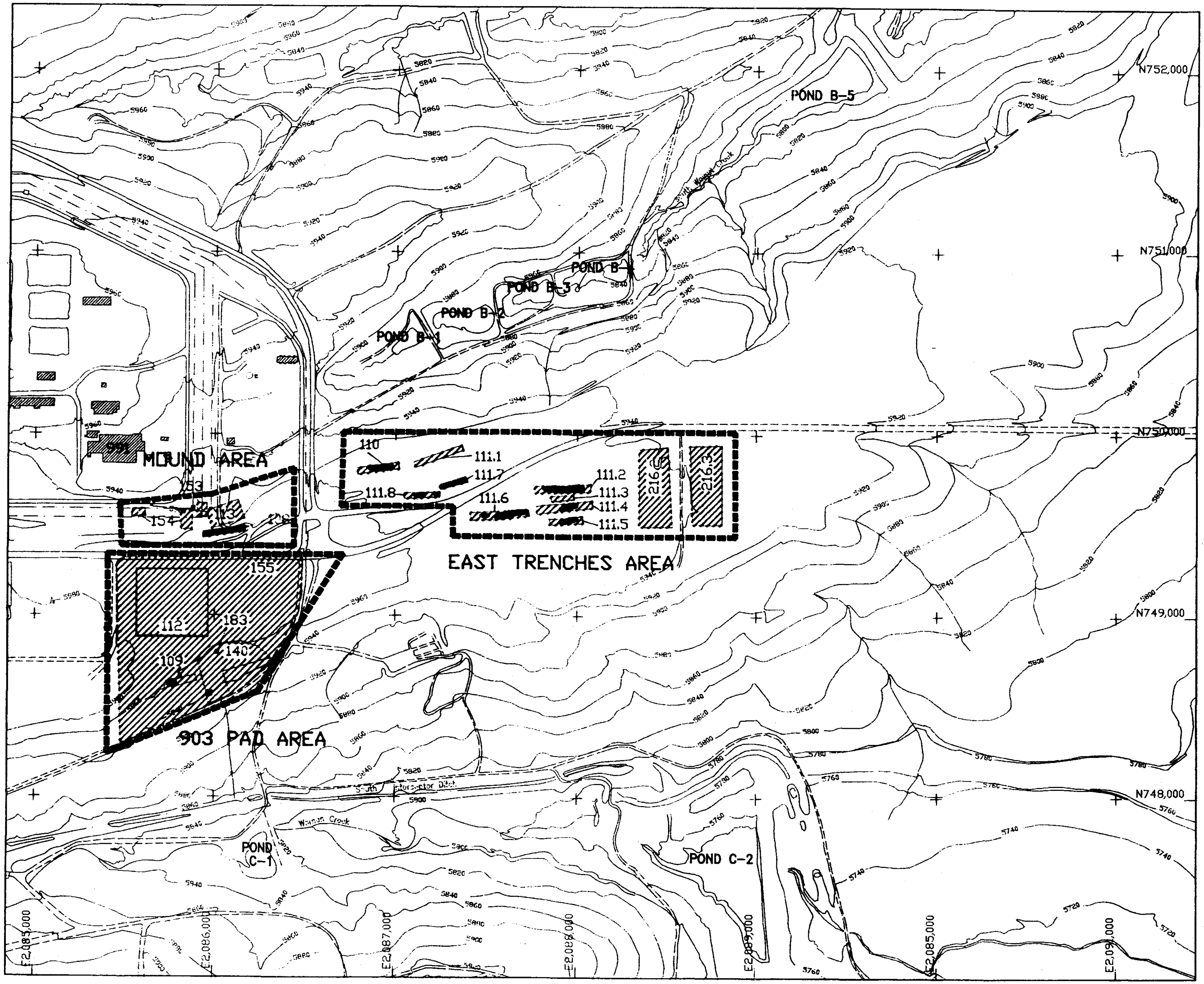


EXPLANATION

216.2 — INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION

LOCATION OF BARRELS DETERMINED BY VISUAL INSPECTION OR MAGNETOMETER SURVEY

SOURCE AREAS

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

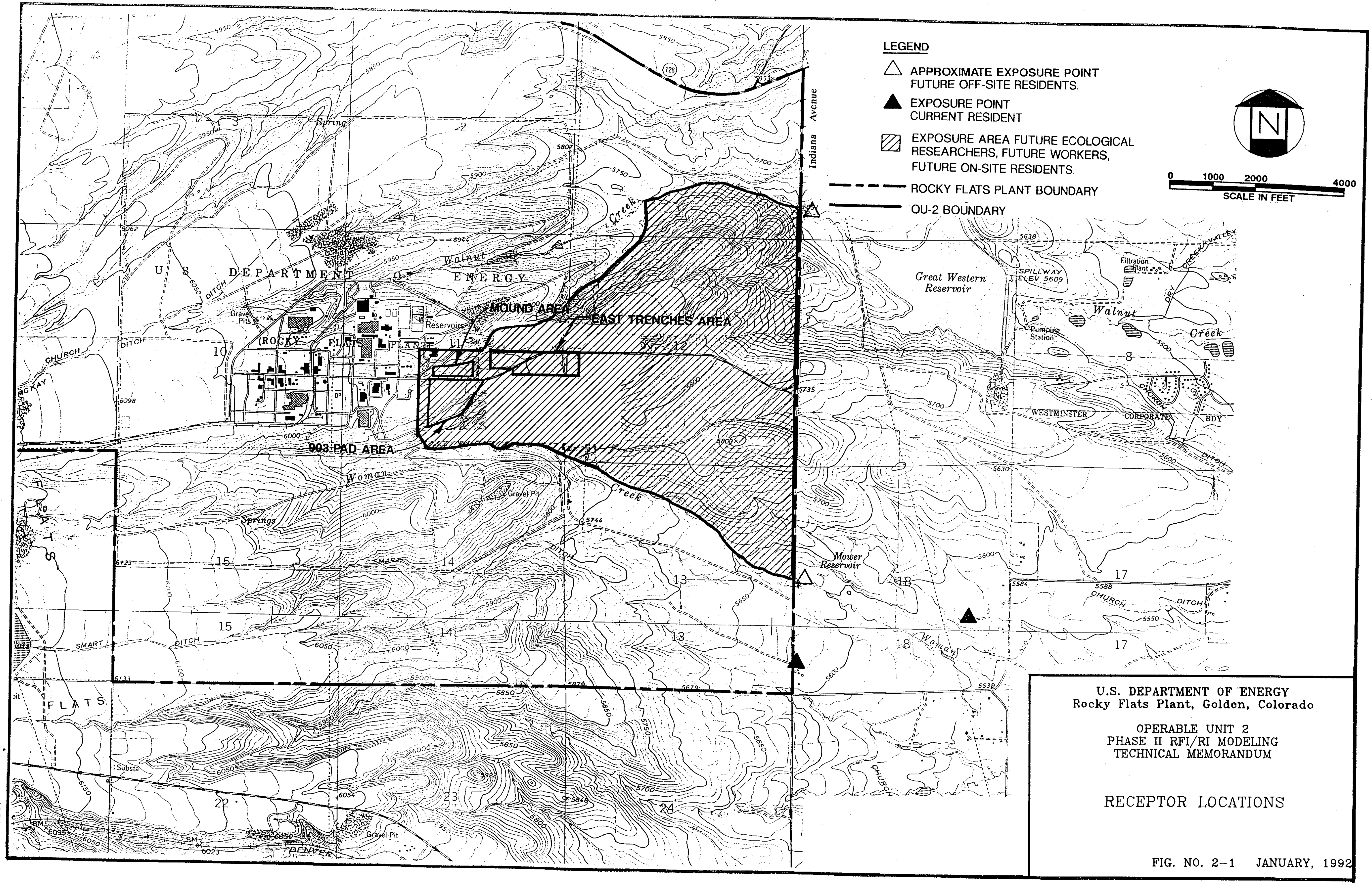
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI MODELING
TECHNICAL MEMORANDUM

REMEDIAL INVESTIGATION AREAS AND INDIVIDUAL HAZARDOUS SUBSTANCE SITES

FIG. NO. 1-2 JULY, 1992

R33M003A.PJJL-062091



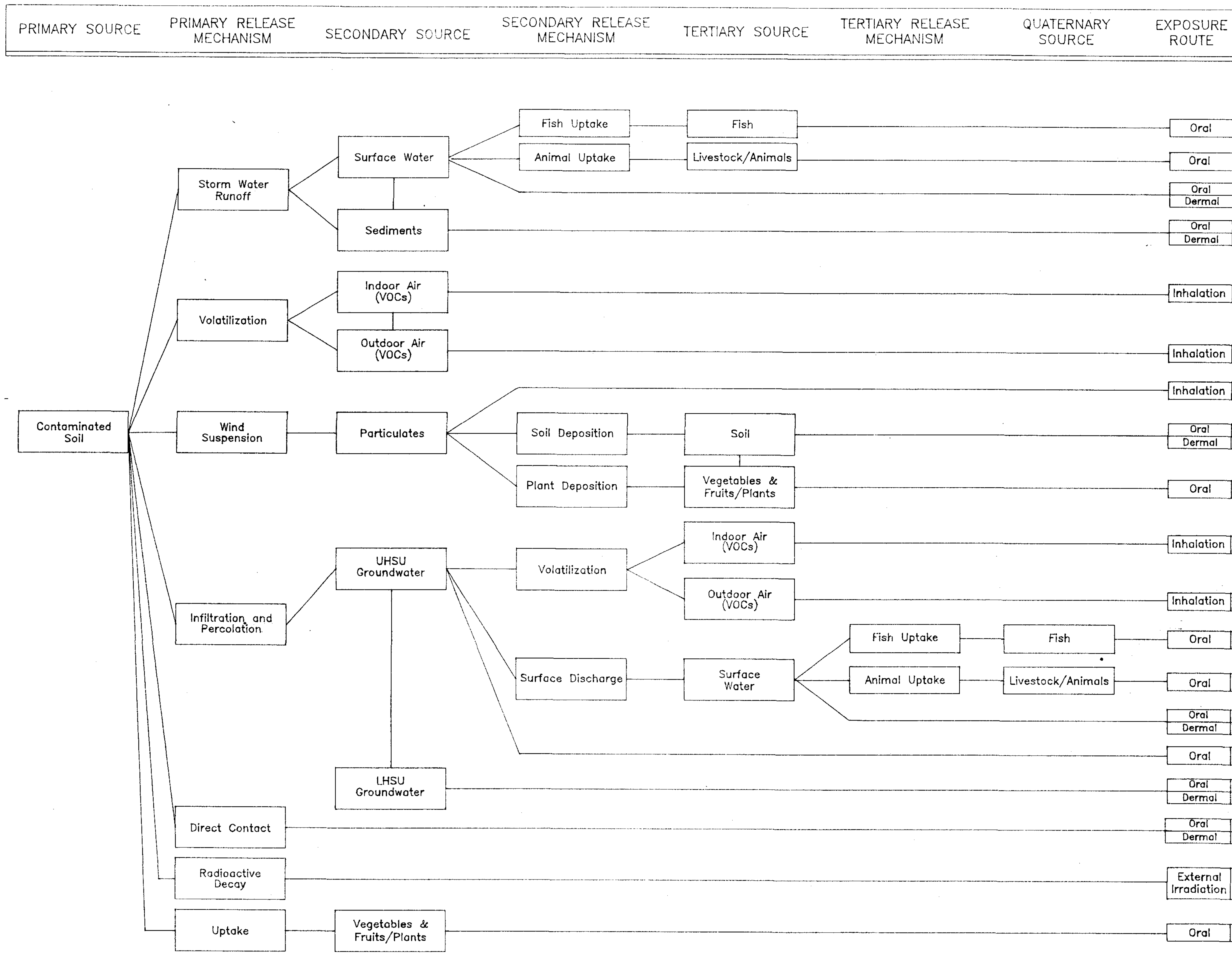
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI MODELING
TECHNICAL MEMORANDUM

RECEPTOR LOCATIONS

FIG. NO. 2-1 JANUARY, 1992

23047037



Exposure Route	Current Off-site Resident	Current On-site Worker	Future On-site Office Worker	Future On-site Construction Worker	Future On-Site Ecological Researcher	Future On-Site Resident: Woman Creek	Future On-Site Resident: Walnut Creek	Future Off-site Resident
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Inhalation	N	N	S	N	N	S	S	N
Inhalation	N	N	N	N	N	N	N	N
Inhalation	I	I	I	I	L	I	I	I
Oral	I	N	N	N	N	N	N	I
Dermal	I	N	N	N	N	N	N	I
Oral	I	N	N	N	N	I	I	I
Inhalation	N	N	S	N	N	S	S	N
Inhalation	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Oral	N	N	N	N	N	S	S	N
Oral	N	N	N	N	N	N	N	N
Dermal	N	N	N	N	N	N	N	N
Oral	N	S	S	I	S	S	S	N
Dermal	N	I	I	I	I	I	I	N
External Irradiation	N	I	I	I	I	I	I	N
Oral	N	N	N	N	N	I	I	N

LEGEND
S = Significant Potential Exposure Pathway
I = Insignificant Potential Exposure Pathway
N = Negligible or Incomplete Exposure Pathway
UHSU = Upper Hydrostratigraphic Unit
LHSU = Lower Hydrostratigraphic Unit

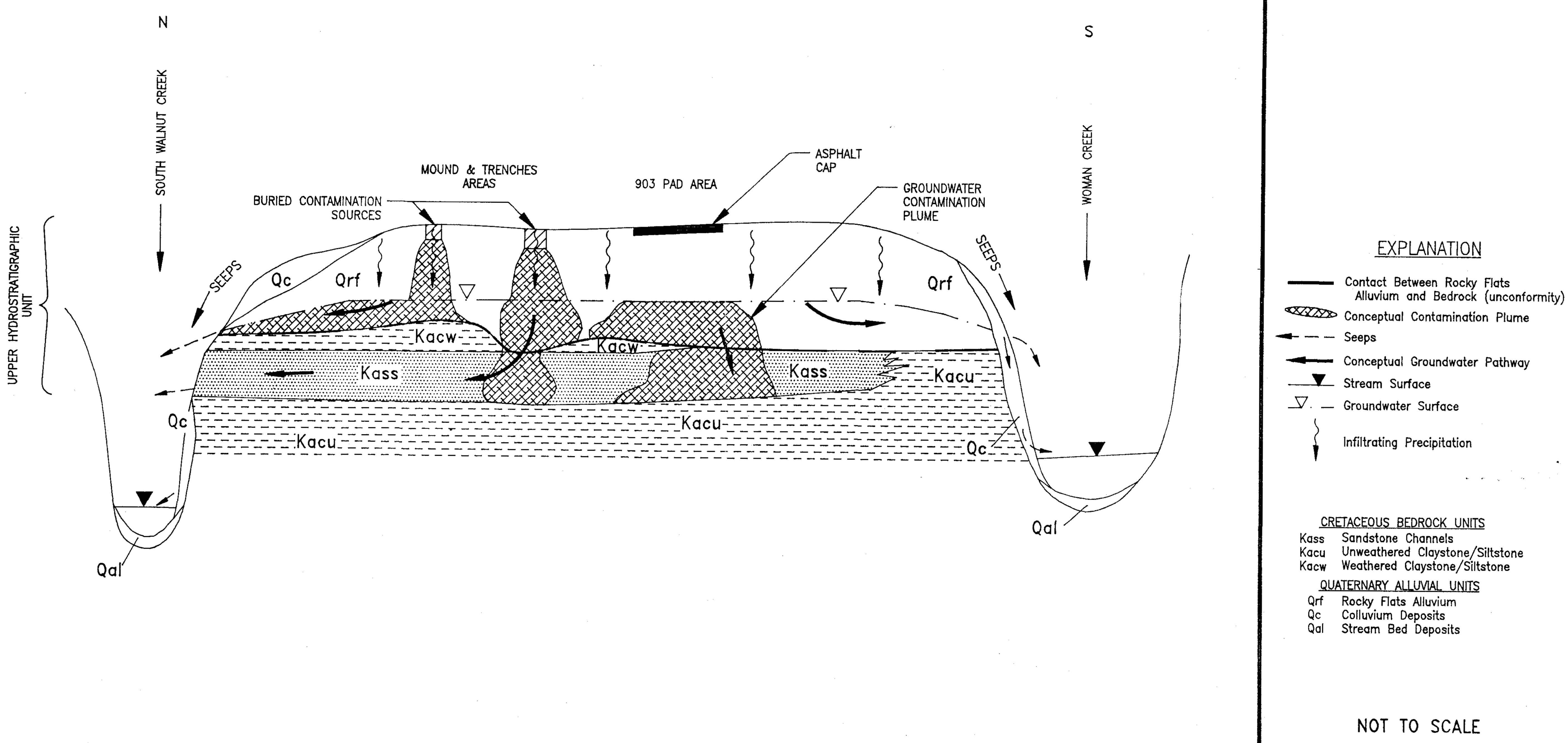
Note: Significant and insignificant potential exposure pathways will be quantitatively evaluated.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 2
PHASE II RFI/RI MODELING
TECHNICAL MEMORANDUM

CONCEPTUAL SITE MODEL FOR ROCKY FLATS OU2

FIG. NO. 2-2 JANUARY, 1993

RFCONC2



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI MODELING TECHNICAL MEMORANDUM

SCHEMATIC DIAGRAM OF SITE
HYDROGEOLOGIC CONCEPTUAL MODEL

FIGURE 2-3

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